NSECT AND FUNGUS PESTS
OF THE FARM

"THE FARMER AND STOCK-BREEDER" MANUALS
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Ministry of Agriculture and Fisheries

INSECT AND FUNGUS PESTS OF THE FARM

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PREFACE

THE volumes in this series are intended to place at the disposal of practical farmers and those who intend to take up agriculture as a profession a summary of the broad scientific principles governing farming on a business basis, and, at the same time, to embody such notes as are necessary to enable these principles to be applied from day to day.

With this object the Manuals have been written as far as possible in non-technical language, and, in order that they may be available at a reasonable price and in a convenient form, all unnecessary detail has been omitted.

It is often made a reproach against scientists, and particularly scientists whose province is agriculture, that they do not take sufficient pains to explain what they are doing, and why they are doing it. The Farmer and Stock-Breeder Manuals have been planned specifically to answer this charge and make available to practical farmers the results of the best scientific thinking and research. In a few cases the

principles laid down may be contrary to current practice, but it should be realized that this fact is in reality a testimony to the value of the series. What is new in scientific farming is not only a question of words but a question of ideas. Ideas divorced from practical experience are of little value, but nothing will be put forward in these Manuals which has not been tested in practice.

H. C. LONG.

AUTHORS' PREFACE

MANY hard words have been spoken of those who, from the office chair, endeavour "to teach the farmer his business," and the authors wish to make it clear from the beginning that they have no intention of attempting any task so dangerous as that of saying what the farmer should or should not do. Their object, rather, has been to discuss from the farming standpoint some of the difficulties due to plant pests and diseases which must be faced on the average farm, and so to indicate the general lines along which these evils may be mitigated and sometimes avoided. Text-book descriptions of the different pests are not given—partly because the latter are mostly only too familiar, and also because they have already been described and illustrated many times in leaflets and agricultural journals. Also no endeavour has been made to formulate cut-and-dried rules for dealing with each individual pest, because, however attractive such instructions may appear on paper, conditions in practice vary so greatly as between one farm and another that the exact method of applying any general principle to a particular case must usually be worked out by the man on the spot. Apart from this, it is impossible within the short compass of this book tc do more than

touch upon certain general aspects of the control of the large number of insects and fungi which prove injurious on the farm.

Although the following pages have not been written for any one special section of the farming public, it is hoped, nevertheless, that they may fill a particular need in the case of those who are about to enter upon an agricultural career, and who will wish to know something of the principles underlying the growing of healthy crops, without entering deeply into entomological and mycological technicalities. Much of the essential preliminary scientific work in regard to agricultural plant pathology has now been done, and further progress must depend largely on the extent to which the agriculturist of the future can be induced to interest himself in the subject, and co-operate in applying scientific principles to commercial conditions.

It is thought also that a book of this type may be of interest to students of economic entomology and plant pathology, as it deals largely with the principles underlying these subjects.

We wish to record our grateful thanks to our friends, Dr G. H. Pethybridge and Mr F. L. Engledow for valuable suggestions.

J. C. F. FRYER.
F. T. BROOKS.

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CHAPTER I

INTRODUCTION

THE growing of crops is one of the many ways in which man has interfered with the normal course of nature, albeit he has been enabled thereby to pass from a nomadic to a settled existence, which has allowed civilized life, as we know it, to become established. The selection and improvement of wild plants for food are the foundation of the fabric of civilization. Primitive man obtained his plant food from fruits and other parts of wild plants scattered over large areas, but nowadays grain and other crops are grown intensively, with myriads of plants of the same kind in intimate contact with one another. In nature a balance has been struck between the relative numbers of the plants found in any locality, and the pests and diseases of these plants are usually kept under strict control by agencies of various kinds.

It is rare to find any natural area of grassland or forest devastated by a pest. This is not due to the complete absence of pests, but is caused by various factors which, under natural

conditions, prevent these pests from multiplying unduly. It is a well-known fact that an animal, harmless or even beneficial in its native haunts, upon introduction into a new country frequently multiplies at such a rate as to become a nuisance: this is usually because the natural enemies of the animal are either completely absent or not sufficiently common in the new country to check the natural increase. In this way the balance of nature is upset. In agriculture man is also upsetting the balance of nature—usually, it is true, to his own advantage, but at the same time not without certain risks which sometimes result in heavy crop losses.

The growing together of enormous numbers of the same kind of plant gives exceptional opportunity for the multiplication of insect and fungus enemies. Consider, for instance, the case of the black Aphis (*Aphis rumicis*), which feeds upon beans: a few individuals reaching a bean-field will find a vast supply of food, breeding will be rapid, and, as one plant becomes overcrowded, the insects will find another within a few inches, and the whole field will soon be infested. The same thing approximately will

happen in the case of a fungus enemy, the spores being blown from plant to plant and so usually falling upon a kind suitable to attack. These conditions are in strong contrast with those of the jungle, where the insect or the fungus spore may have to travel long distances, running all sorts of risks on the journey, before meeting with a susceptible kind of plant.

Then, again, on the prairie or in the jungle the survival of any plant is wholly dependent on its ability to withstand not only the competition of its neighbours, but also the attacks of any animal or fungus of which it is the food. As a result every weakly plant is exterminated, and only those persist which are constitutionally able to overcome all adversities with which they may meet. This is a very different state of affairs from the conditions surrounding the cultivated variety of plant. Here man has selected his varieties primarily in regard to some single characteristic—as, for instance, the ability to yield food—and with this object he has retained plants which are but partially resistant to insect and fungus attack, and which would never have survived in the wild state. Farming

therefore has upset the balance of nature in at least three ways: it has given to certain insects, fungi, etc., an assured and easily available food supply; it has permitted varieties of plants specially susceptible to their attack to survive; and it has freed these pests from many of the controlling influences to which they were subject before the days of cultivation. It is natural then that these insects, fungi, etc., placed in such favourable surroundings, should multiply unduly and become pests. In the succeeding chapters are described some of the measures which can be taken to restore again the proper balance between the crop plants and the organisms which prey upon them.[1]

[1] The scientific names of the different pests and diseases mentioned in the following pages are not always given in the text. When omitted, they will be found (in parentheses) after the English name in the Index.

CHAPTER II

SYMPTOMS

If under the conditions of the jungle or prairie a seed falls upon unsuitable soil, the resulting seedling is unable to compete with other kinds of plants for which the soil is suitable, and it is therefore choked and killed. The same thing happens if the seedling finds itself under climatic conditions which do not suit it. In agriculture, however, the attempt is often made to grow crops under conditions of soil or weather which would never allow the plants to persist if they were in a wild state, and therefore symptoms of ill-health will inevitably appear—altogether apart from the presence of noxious insects or fungi. Certain kinds of soil that show an alkaline reaction are unsuitable for oats, which become affected by the disease known as "grey-leaf," characterized by the presence of large, irregular, discoloured patches on the foliage. A farmer soon learns by experience which of his fields, if any, are liable to this trouble, and crops them accordingly. Occasionally, too, the character of the soil becomes

changed by ill-balanced manurial treatment, which may result in ill-health in succeeding crops. Even excessive applications of lime may cause disturbances in crop growth.

Weather conditions frequently cause a check in plant growth, and though, upon the resumption of more favourable weather, normal growth is resumed, there may be some permanent injury. During a wet spring, barley on comparatively low-lying land may show yellowish foliage in consequence of partial waterlogging of the soil causing a temporary deficiency of available nitrogen compounds. When the soil becomes drier, nitrification proceeds normally and the crop regains a healthy colour, though the check it has received may cause a certain loss of yield. Where yellowing of such a crop is due to excessive water, drainage improvements may be expected to prevent a recurrence of the trouble.

It is therefore clear that ill-health in plants may be due to agencies other than pests, and although this book is concerned chiefly with the latter, the importance of being able to recognize whether a failure is due to unsatisfactory

conditions for the growth of a crop or to favourable conditions for the attacks of fungi and insects is obvious. For this reason some attention must be devoted to the nature of the injuries caused by pests to plants.

Of these, perhaps the most obvious are those which are due to such small animals as insects, slugs, snails, eelworms, etc. In such cases the crop forms their natural food, but the manner in which they take this food varies considerably, causing different symptoms in the plants attacked —symptoms which are of great value in attempting to discover the cause of the trouble. Of the insects which attack farm crops some are provided with cutting jaws, with which they are able to bite off pieces of the plant. Caterpillars for instance, and such beetles as the turnip flea, often eat the leaves or stem above ground, and the characteristic cuts or holes so caused indicate the nature of the pest even though the latter may not easily be discovered in the daytime. Slugs and snails also eat the leaves of various crops, but, as they are provided with an apparatus rather like a rasp in place of biting jaws, the injury is different, and, instead of

making clean cuts, they leave a rough, frayed edge which is fairly characteristic. Many biting pests work below ground, feeding sometimes upon roots, but more often upon the underground stem just above the roots, as in the case of the wireworm. The result is that the top of the plant becomes severed, or partially severed, from the roots and shows characteristic symptoms—for instance, in the yellowing of the flag in a cereal. Again, a very important series of pests—the maggots of various flies—have a mouth "apparatus" which can hardly be described as jaws, but consists of sharp, hooklike organs, something like claws, with which they tear off pieces of the plant. Some of these live in the soil, as in the case of the leather-jacket, but more of them, such as the frit fly and the mangold fly, live inside the plant, burrowing into the interior and feeding upon some special part. Thus the frit fly destroys the growing point of the oat, causing the central leaf of the attacked tiller to turn yellow and die. Growth upwards is prevented, and the shoot in consequence is useless and cannot produce an ear. Or, again, in the mangold fly

the maggot burrows in the leaf, eating out the substance and causing an empty blister. Leaves badly attacked are thus unable to do their share in the work of nutrition, and if many leaves are attacked the whole plant is stunted, or even killed.

These, however, are not the only means by which insects feed upon plants; there is another very important group of pests, among which the Aphides (dolphin and greenfly) are conspicuous, which feed only on the sap and not on solid matter. Their method of feeding is to pierce a hole into the plant with a special *trunk or proboscis and then to suck the sap.* Each puncture usually shows first as a light-coloured spot. Often this spot is so injured by the loss of sap that it dies, and perhaps becomes a brown area. Or, again, in the case of a young leaf or stem, growth is prevented wherever there is a puncture, with the result that the leaf or stem becomes curled or distorted. A cabbage or swede leaf damaged in this manner must be familiar to most farmers.

Finally, reference may be made to one other class of damage — that caused by eelworms,

which are minute worms seldom visible without a microscope. These worms live inside the plant, and although it is clear that they feed upon the plant juices, the exact method by which they cause so much damage is hardly known. In the case of the beet eelworm, which lives within the smaller roots, stunting of the plant is the result, possibly due simply to a blocking of these roots; but in other cases—as, for instance, in that of the stem eelworm in oats or clover—the whole plant becomes swollen and diseased, while in the case of yet another eelworm (that which causes ear cockles in wheat), a black gall full of eelworms takes the place of the wheat kernel. Much more could be written upon "symptoms," but enough has been said to indicate that the superficial appearance of the crop will serve in most cases to give a very fair idea as to the kind of pest responsible for the trouble, even though the precise insect, etc., may be hiding away, may be too small to be seen with the naked eye, or may have disappeared altogether.

Complete or partial crop failure may also be due to parasites which are themselves plants

or plant-like organisms. The most serious of these parasites are fungi, all of which, being devoid of the green colour of the higher plants, have to obtain their food from living plants or animals or from the substances manufactured by them. The reproductive bodies of fungi are exceedingly small, and are called spores; they correspond to the seeds of flowering plants. Slime-fungi (*e.g.* the parasite causing finger-and-toe or club-root disease of turnips), minute bacteria, and the even more obscure "viruses," also produce disease in crop plants. Diseases caused by these plant parasites show great diversity of character, but in general they are less local in their effect on the plant than are insect attacks. Some fungi kill outright the plants attacked, as in clover rot, but they may so transform the saleable part of the crop as to render it useless, as in bunt of wheat, or may render it of less value, as in the common potato scab. Many fungi diminish the yield by a steady withdrawal of food from the crop, as in the attacks of rust fungi on cereals. In nearly all cases of attack by these plant parasites their development is particularly insidious, and usually

the damage is done or has become inevitable before the fungus is visible. It is only the reproductive parts of these fungi which are usually seen by the naked eye, the feeding organs being minute threads or spawn embedded within the plant and invisible except under the microscope.

Notwithstanding the minute size of most of these plant parasites their presence can often be detected by the symptoms they produce in the plants attacked. If, for instance, a farmer sees that some plants in a lucerne ley are flagging or wilting on a hot day, while others are normal, it is an almost certain sign that the wilted plants are attacked by a disease of fungoid origin known as "crown-gall" or "crown-wart." If such plants are examined, large gall-like swellings will be found growing from the root-stock. Spots on the stems and leaves of crop plants are often due to fungi. On the leaves of cereals, for example, small yellow or brown spots denote rust attack, and whitish patches indicate mildew. Black spots on potato haulm are the first signs of attack by the blight fungus, and long brown streaks

in the leaves of barley are one of the signs of the disease which is also a cause of blindness of the ears. Some diseases of the "virus" kind produce a general transformation of the shoot system of the plant, which may result in a rolling of the leaves and a considerable dwarfing of the plant, as in "leaf-roll" of potatoes. The smutty ears of cereals are due to certain parasitic fungi. Some of these organisms cause also a rot of the parts attacked, as in the blackening of clover plants by the "clover-rot" fungus. Potato tubers attacked by blight show at first a brownish discoloration, seen through the skin, which is often followed by a wet rot induced by other organisms. Lastly, some fungi and allied parasites produce monstrous growths or swellings in the organs attacked, as in wart disease of potato tubers and in finger-and-toe disease of swedes and turnips.

CHAPTER III

WEATHER

It is difficult to overestimate the influence of weather conditions upon the incidence of insect and fungus pests. Like all other organisms, insects and fungi can develop only under certain environmental conditions, in which weather plays the dominant rôle. Weather represents the result of an aggregation and interaction of many factors—such as rainfall, atmospheric humidity, temperature and wind force; any one—or any combination—of these factors may favour the development of a pest, resulting in a great increase of it and in the possibility of more widespread infestation than usual. At the same time, weather conditions which favour the insect or fungus may depress the vitality of the crop, so that the attack is intensified in this way also.

Fungi. — Fungi are exceedingly delicate organisms, and, in the growing state, cannot usually withstand exposure to a dry atmosphere. Wet weather therefore generally favours the development of fungus diseases. Most fungi

infect plants in consequence of their spores alighting on the surface and there emitting under moist conditions delicate tubes or threads which penetrate the tissues of the plant. With insufficient moisture on the surface of the plant the spores either do not germinate, or, if they do, the delicate threads arising from them immediately collapse. With such a disease as potato blight, caused by the fungus *Phytophthora infestans*, the summer rainfall and relative humidity of the atmosphere mainly determine whether the disease will be epidemic or merely sporadic. In extremely wet seasons, if the temperature is also suitable, this fungus may sweep through large fields of potatoes in the course of a few days, causing a complete blackening of the haulm. In a dry summer, on the other hand, the fungus will merely affect a leaf here and there, and no appreciable harm is done. In general, less damage is caused by potato blight in the eastern counties than in the west of England, and this difference is directly correlated with the heavier rainfall in the latter. With potato blight, too, a considerable degree of moisture in the soil is

necessary to allow of infection of the tubers, and in very wet seasons, when the water-content of the soil is high, other destructive organisms follow in the wake of the blight fungus, causing a partial or complete rot of the tubers. In the past, potato famines have been caused in Ireland in very wet seasons owing to destruction by blight and other tuber-rotting organisms.

Fungi and allied organisms which chiefly attack roots and tubers are also greatly favoured by excessive moisture in the soil. Finger-and-toe disease of turnips and powdery scab of potatoes are always most severe in a wet season. On the other hand, such a dry summer as that of 1921 may almost completely inhibit the development of troubles of this kind: in that year the soil was so dry that, in certain areas infested with the organism causing wart disease of potatoes, tubers which would have become seriously attacked under average weather conditions remained perfectly clean.

At harvest time, too, excessively wet weather enables certain mould fungi to develop unduly on the grain, seriously injuring its appearance

and reducing its quality, whereas under dry conditions these fungi are entirely innocuous. From every point of view it is desirable to complete the harvest as soon as possible, and not least in order to prevent deterioration of quality through attack by moulds during a wet spell.

There are fungi belonging to one class, however, which are often favoured by comparatively dry weather. These are the mildews. Peas and swedes are not infrequently more affected by mildew in a dry than a wet season.

The conditions of temperature also have a marked influence upon the development of fungus diseases of crop plants. Within certain limits, fungi, like most other plants, grow faster at relatively high than at low temperatures. There is a certain temperature for each fungus at which it grows best, and it can readily be understood that if the temperature favours the parasite, and at the same time impedes the crop plant, disease of a serious kind will probably result. If, on the other hand, the temperature favours the crop plant, the latter may grow right away from the fungus pest. Under

certain conditions the temperature may be either so high or so low as to kill the germs of the parasite. Many fungus spores are delicate structures and cannot readily resist extreme temperatures. The common yellow rust of wheat (*Puccinia glumarum*) practically disappeared from the eastern counties of England for several months after the hot summer of 1921 owing to the spores being killed by prolonged high temperatures. One of the factors tending to prevent the serious black rust of wheat (*Puccinia graminis*) from becoming a scourge in this country is the inability of one of its types of spores to withstand the vicissitudes of our winter temperatures.

It is often difficult to separate the influence of temperature from that of rainfall in determining the relative effect of these environmental factors. In such a climate as that of the British Isles dry weather in the summer usually implies high temperatures, and wet weather is generally accompanied by cool conditions. In this country the relative rainfall is usually of greater importance than the temperature in determining the incidence of fungus pests. As an illustration

of the difficulty of evaluating some of the factors which determine whether disease will arise or not, the incidence of bunt in wheat may be cited. Autumn-sown wheat is nearly always more seriously attacked by this disease than is spring wheat, but it is not yet known how far the temperature and the moisture-content of the soil at the time of germination of the wheat respectively determine this difference in attack.

Wind is a very potent factor in the dissemination of many fungus diseases, and many kinds of spores are carried in a living condition over considerable distances. The view formerly held, that spores in an infectious state could be carried hundreds of miles by wind and then commonly cause infection, has, however, been modified. It is now usually considered that some definite means of contact-carriage—*e.g.* by seeds, tubers or purely mechanical agency—is chiefly responsible for the dissemination of fungus diseases over wide tracts of country.

It is under extreme conditions of weather that the relation of fungus diseases to the weather is most clearly seen. Very wet weather

nearly always favours these troubles, while dry conditions often reduce them to negligible proportions. Under average weather conditions the incidence of fungus diseases will hover around a mean, the exact intensity being dependent upon a multiplicity of factors which it is often difficult to analyse clearly.

Insects.—The effects of weather upon insect pests seem perhaps more obvious, but for all that they are sufficiently complicated and require much more study than they have received up to the present. All kinds of insects are not favoured by the same weather conditions, and, equally, conditions which harm one kind of pest may cause another to increase. It is often supposed, for instance, that a hard winter brings about a reduction of insect pests. This is perhaps true as regards Aphides (greenfly, etc.), but it is almost certainly not true in regard to moths, the caterpillars of which are often more destructive after a hard than a mild winter, and it is but doubtfully true as regards wireworms. The reason for this is that during an open winter the enemies (birds, moles, field-voles, predaceous beetles, etc.) of chrysalides, cater-

pillars and such soil pests as wireworms can feed during the whole season, while during long periods of frost the pests are safely sealed up underground and are secure, for it takes more frost than usually occurs in Britain to destroy them. Some caterpillars, for instance, can be frozen so hard as to be as brittle as a dry stick, and yet after such a freezing they remain alive and can become active when the thaw comes. It is not easy, therefore, to give the reader one or two broad generalizations which will enable him to judge from the weather what pests are likely to become troublesome; but as the space available for this subject is too limited to permit of many species being considered separately, some attempt to generalize must be made.

In the first place, it should be mentioned that most insect pests occur in more than one form: usually each one starts as an egg, and from the egg an immature insect hatches —the larva—which, as in the case of caterpillars or fly maggots, is very different from its parents, or, as in the case of Aphides, may be much the same. The larva feeds for a

period, and then, in some of the most important families of insects—such as moths, beetles and flies—it turns to a "pupa" or chrysalis, which does not feed, and in which the final stage, the adult insect, is developed. The egg stage in insects is normally very resistant to differences in weather conditions, which delay or hasten hatching, but seldom cause death; the newly hatched larva is, however, often quite the reverse. The young leather-jacket, for instance, appears unable to withstand hot, dry conditions; leather-jacket epidemics therefore occur after a damp, moist summer and autumn—as, for instance, that of 1924. On the other hand, the young "cutworm," the caterpillar of the turnip moth, appears to be unable to flourish under wet conditions, but is happy when the weather is warm and dry. Young cutworms are hatched towards the end of June and early July, and therefore, when this period is warm and dry, damage by cutworms at the end of July and in August is not unlikely. The same conditions—warmth and absence of heavy rain—suit young Aphides (and old ones also), for they are very delicate insects and are easily destroyed

by rough weather and cold rainstorms. As regards the "pupa" or "chrysalis" stage, the condition of the insect is certainly delicate and susceptible to injury: a wireworm pupa, for instance, will die very rapidly in the sun; but this characteristic is not of much importance, for every insect, when it is about to pupate, is very careful, if it has to spend any length of time as a pupa, to place itself in such conditions as to be relatively safe from the weather. This it secures either by burrowing to a considerable depth in the soil, where a little cell is hollowed out (and often cemented with "saliva"), or by making a cocoon of silk or other material. The effects of weather on pupæ are therefore not very obvious, though it may again be emphasized that a frosty winter is usually beneficial to pupæ, as it protects them from their enemies.

In regard to adult insects, the majority seem to like sun and warmth; it is the adult insect which lays the eggs and spreads the species over the country. For this work the majority of insects require more or less fine weather—at any rate without incessant rain or abnormal cold.

So much for the insect itself. But weather

does not affect the insect alone! Its importance in regard to the crop is at least as great. It may be taken that any weather which hampers growth, especially in the early stages of the crop, is likely to result in increased damage by insects. Such conditions may or may not be beneficial to the pest, but in any case, by preventing the regular production of roots or foliage, the plant cannot keep up with losses caused by insects, and even quite a small number of the latter may then bring about more destruction than would have resulted from a plague of insects upon a rapidly growing crop. The weather may cause evil results of a similar character by delaying the sowing of a crop, so that, even though growing vigorously, it may still be too young to withstand the onslaughts made upon it. Plenty of instances of these effects will be found in the following pages, and all that remains is to attempt a very rough and approximate summing up, as follows:—

1. Little faith should be placed in a hard winter; it will harm some species of insects, but favour others.

2. During a spring (April, May or early

June) drought, insect damage is likely, as the weather will probably benefit the insects and retard the crops.

3. During a bright, sunny summer, insects in general, and aphides and caterpillars in particular, are likely to be abundant.

4. During a cold, wet summer, insects are less likely to be harmful, but slugs and eelworms will increase.

5. After a wet summer and autumn, leather-jackets, slugs and eelworms are likely to be troublesome.

CHAPTER IV

NATURE'S PEST CONTROL BY PARASITES

FORTUNATELY, although man's interference with nature has given pests a very definite advantage, other species which previously kept them in check are still active to a greater or lesser extent. As regards fungi, the dominant controlling factor is undoubtedly that of climate or weather, which has been discussed in the previous chapter. Insects, like fungi, are greatly influenced by weather, but their numbers are also much reduced by birds, by parasitic or predatory insects, by diseases, and even by the attacks of fungi. Of these pest-destroyers, parasitic insects such as ichneumon flies, or predatory insects such as ladybird beetles, are of first importance. The latter attack their prey in a "straightforward" manner, seizing it in their jaws and sucking or eating it much as a stoat deals with a rabbit. Anyone who cares to watch the black-and-yellow-spotted ladybird grub eating its way through a colony of "black aphis" or "fly" upon a bean plant will realize the process. Ichneumon and chalcid flies (really relatives of

the wasp) go to work in a more insidious manner, which leads to their good work being less generally recognized. The usual method of attack is for the female to lay an egg in or upon her prey, which may be almost any insect from an aphis to a caterpillar. After a few moments' discomfort the insect so treated resumes its normal mode of life, but before long the egg hatches into a grub, which feeds upon, or more often within, the unfortunate caterpillar or aphis, being particularly careful to eat first the unimportant organs only. The caterpillar thus goes on eating the plant, and the parasitic grub continues to eat the caterpillar until the parasite has almost eaten enough. It then finally devours the last essential organs of its prey, which dies: the grub turns to a pupa, which in its turn gives rise to the full-grown fly, and the whole process begins again.

The fact that pests are subject to the attacks of many parasites and other enemies often gives rise to the question as to why there are any pests left. The answer to this is partly that the parasites themselves are subject to the attacks of their own special diseases or parasites; but,

even without them, the pest would probably survive, as the following considerations show. In the case of animals which prey upon others the multiplication of the former is dependent upon the food supply—that is to say, when prey is abundant and easy to get, the numbers of the hunting animal increase, but as soon as food becomes scarce they decrease, owing to death from starvation and the prevention of breeding by lack of nourishment. Before, therefore, a hunting animal can become plentiful, its prey must first be available in abundance, and this applies not only to large animals but also to the smaller ones, such as ichneumon and chalcid flies.

What usually happens then in the case of insect parasite and pest is somewhat as follows. First the pest increases beyond all bounds; abundant food is offered to the parasites, which also increase until they have so reduced the pest that prey is very hard to find. Most of the parasites therefore die out: the few pests which have escaped increase in numbers until the few parasites left again have their chance. Thus the usual sequence is first a year—perhaps

two or three years—in which a certain pest becomes very numerous, then a period in which it is scarce, and so on. Sometimes these fluctuations in numbers of a pest due to parasite attacks are small, as when the rates of breeding of pests and parasites are more or less balanced; but more often the pest is capable of a more rapid multiplication than the parasite, and then typical epidemic outbreaks are caused. In any case it is obvious that, valuable as parasites are, they cannot be expected to exterminate their prey, for if they were capable of doing so they would destroy their own livelihood, and neither pests nor parasites would exist.

Parasitic fungi are not controlled by insects, but their spores may be disseminated through contact with them. Comparatively few fungi attack other fungi, and there is no common fungus disease of crop plants which is appreciably reduced in consequence of attack by another fungus.

CHAPTER V

PRINCIPLES OF PEST CONTROL

MANY of the pests and diseases which attack cultivated plants cannot be combated directly with reasonable hope of success, but frequently there is some means by which they may be evaded altogether or reduced to insignificant proportions. As in medicine, "prevention is better than cure," and the farmer will prefer methods of prevention and evasion rather than those involving costly remedial treatments, even where such are available.

Insects.—As regards insects, it is indeed this element of cost which renders a direct attack upon the pest so difficult. The profits on the average crop are so small, so speculative, and so dependent on factors outside the farmer's control, that it is beyond his powers to invest any considerable sum in the destruction of insects. Take for instance the application of a soil insecticide: it seems hardly likely that any chemical will prove successful unless applied at the rate of 4 cwt. per acre—even this means

only 1 part of the chemical to about every 4000 parts of the top six inches of soil, or, put in another way, less than ½ lb. of insecticide to every ton of soil! Yet this potent chemical must be produced at about 10s. per cwt. to make it at all attractive: at £1 per cwt.—*i.e.* £4 per acre—a reasonable profit on the investment could seldom be expected in the first year, though it might ultimately be won by the additional return on subsequent crops in the rotation, owing to freedom from soil pests.

It is thus clear that in agricultural entomology the pest must be attacked not so much by adding new operations to the ordinary programme of the farm, but rather by making such small changes in the ordinary cultural practice as will continually put the insects at some disadvantage. The most important of these adjustments in relation to pest attack are:

1. Variations in the rotation and arrangement of cropping, such as the substitution of a crop less liable to attack for one which has proved itself very susceptible, and the planning of the fields so that a crop very subject to insect

injury (*e.g.* mustard seed) is as far as possible from the field which carried this crop the previous year.

2. By timing the growth of a crop so that it is not at the stage when it is most susceptible to a pest just when the pest is present in its maximum numbers. (It is true that weather conditions too often decide when a crop can be sown, but since even the gain of a week by the crop may make a very great difference in the extent of attack by pests, there is not infrequently an opportunity of taking advantage of this method.)

3. By encouraging healthy growth—as, for instance, by the use of manures or cultural operations. This may seem too obvious to be worth mention, but it nevertheless deserves more detailed attention than it usually receives, chiefly in regard to the time when the appropriate measures are taken. A top-dressing, for instance, which would have been applied in ample time to benefit a healthy crop might be almost wasted on a diseased crop, owing to the fact that the plants were becoming too damaged to take advantage of the dressing, although the

latter might have been quite effectual if applied a fortnight earlier.

4. By "Farm Hygiene"—that is to say, by reducing to the minimum possible, breeding grounds and shelter for pests. Of all measures this is apparently the most unsatisfactory, since the results of the work cannot be seen or measured, but it is probably as important, in the long run, as any other means of reducing damage by pests.

It is thus clear that the chief methods of dealing with injurious farm insects are aimed either at preventing the appearance of the pest in numbers, or, where that is impossible, of dealing with the situation before the attack has fully developed.

Fungi.—With crop diseases caused by fungi, even more than with insect pests, when once disease has become well established direct attack is usually valueless. The chief lines of preventive treatment as regards diseases caused by fungi and allied organisms are as follows: the use of clean seed, the use of varieties resistant to or immune from disease, methods of cultivation which render it more difficult or impossible

for diseases of this kind to become established, proper manurial treatment, and the destruction of diseased material (plant hygiene).

Although these methods of prevention will be dealt with fully in subsequent chapters, we may give here a few illustrations of certain farm practices which result in the reduction of disease.

An instance of a change in the rotation to counteract a parasite is afforded by the practice in parts of Scotland, where finger-and-toe disease is rife, of extending the duration of temporary grass leys so as to lengthen the interval between two successive turnip or swede crops.

The eradication of weeds on arable land is necessary from many standpoints. Altogether apart from competition with crop plants for the food available in the soil, weeds often harbour the same diseases as those which afflict cultivated plants, besides being a prolific source of insect pests. Cruciferous weeds such as charlock are often affected by finger-and-toe disease, and, unless destroyed, may be the means of allowing this parasite to persist during that part of the rotation when crops not susceptible to it are being grown. In this connexion barberry

bushes in the neighbourhood of cereal crops must be looked upon as weeds and eradicated accordingly, for the barberry probably forms the sole means in this country by which the serious black or stem rust of cereals can survive from one season to the next. This disease was formerly widespread in England, and the agricultural writers of the eighteenth and early part of the nineteenth century make frequent reference to its destructive character under the name of "mildew." Long before it was proved scientifically, farmers felt that there was some intimate relation between barberry bushes and the occurrence of this serious disease of wheat. There has been an almost complete extirpation of barberry bushes near arable land in more recent times, and at the present day black rust of cereals is relatively unimportant in this country.

Even slight changes in methods of cultivation will sometimes considerably reduce the incidence of certain diseases. Deep earthing-up of potatoes may make considerable difference to the incidence of blight in the tubers. The disease in the tubers arises from spores which, formed on the haulm, are washed down by rain

through the soil, so that the deeper the layer of soil above the tubers the less liable are they to infection.

In the clover crop the disease known as clover rot, due to the fungus *Sclerotinia trifoliorum*, which causes blackening and death of large numbers of plants, is most to be feared. The disease is checked, but sometimes not entirely prevented, by extending the rotation. It is most liable to occur during the first autumn or early winter after sowing, and is especially serious when the foliage is luxuriant. Good results have been obtained in checking the disease by allowing sheep to eat off the strong growth. This "sheeping off" has the effect also of consolidating the ground, which prevents in some measure the spread of the fungus. It is noteworthy too that clover in its second year is less liable to this disease than in the first year. In districts where clover rot is prevalent, it is often advisable, in whole or in part, to replace the clover with sainfoin (especially on chalky soils) or with trefoil, both of which are usually less susceptible to this fungus.

"Local Adaptation" of Crop Varieties.—Each

crop plant has a certain range of soil and weather conditions within which alone it can be grown successfully. Even where a crop can be grown with moderate success, the yield of some varieties may be insufficient to give an economic return, so that the farmer selects his varieties and his land with the object of obtaining the maximum yield per acre. It is a matter of common observation that certain varieties of crop—*e.g.* wheat—grow better in some localities than in others. For instance, Rivet wheat will give a good yield on land that is too heavy and cold to carry a crop of the more commonly grown bread wheats. This principle of "local adaptation," as it may be called, has long been recognized by farmers, and is of the utmost importance in profitable crop production.

Farmers' Experiments.—The modern farmer possesses a vast store of knowledge about crops which has been handed down by tradition, and which he has supplemented by his own observation and experience. Many agricultural practices are the outcome of centuries of experience, and, when subjected to exact scientific experiment, are shown to be the best possible after taking

into account the economic and other factors influencing farming in the district. This of course is not unnatural, for farming is too precarious a business to permit the inefficient to survive indefinitely. Most farmers therefore are either deliberately or—perhaps more often—unconsciously carrying out scientific investigations, as, for instance, by trying some new variety or new farm implement; in the long run, farming opinion, based upon innumerable trials up and down the land, will correctly sum up the value of the novelty. This, however, is a rather slow process, and the individual farmer can in his own case get more rapidly to the true answer first by keeping closely in touch with whatever scientific agricultural institute may be near him, and then by cropping a field so as to make a definite experiment. The scientific station can plan its experiment in such a way that the same plot is sown in duplicate and triplicate, and thus errors due to variations in soil, etc., are avoided. This multiplication of small plots is not a commercial possibility on most farms, and must usually therefore be left to the experiment station.

The farmer's experiment, therefore, is rather as follows. Suppose that an experiment station discovers that potato-spraying with some special fungicide increases the yield by perhaps two tons an acre: the farmer then wants to know whether the treatment is going to pay on his particular farm. He will therefore make his own experiment, but in doing so there are several points which are of great importance if the result is to be true: (1) Obviously, part of the crop must be treated and part left untreated. (2) Both treated and untreated parts must be on soil which is as similar as possible. (3) The variety must be the same throughout, and equally so must the manuring. (4) Lastly, the crop on the respective portions should be weighed and not merely guessed. Even so, more than one season may be necessary to get the true result.

Evidently the whole trial is distinctly troublesome to a busy man, but, as a true result may mean money in pocket for subsequent years, it is well worth while. Here the suggestion may be thrown out that nowadays a good deal of assistance is available. In most counties there are agricultural organizers employed by the County

Councils, who can be called upon, while every county is attached to some institution at which there is both an entomologist and a mycologist, whose help has only to be asked for. The two latter, in most cases, have a good knowledge of ordinary farm practice, but even where they do not appear to have it, their help should not be despised on that account, for in regard to the disease or pest they will be able to ensure that the experiment is properly planned, and can assist the farmer very greatly in calculating the result.[1]

Varieties resistant to Disease.—So far as new varieties resistant to disease are concerned, scientific institutions and practical plant breeders will continue to be chiefly responsible for new discoveries, although it is always worth while to be on the look-out for individual plants of super-excellent quality, as not infrequently in the past some of the most desirable varieties of crop plants have been discovered in this way. If the farmer observes such superior plants in a crop, he can either hand them over to some firm or scientific institution for adequate test,

[1] See p. 194 for list of Advisory Centres.

or, alternatively, he can increase the bulk himself until large field trials can be made, although this requires much time and attention. The more intensively cultivation is carried on the more likely is the cultivator to select for himself particular strains of crop plants. Many horticulturists for instance possess special strains of plants which they have themselves selected and which they maintain year by year. The watch for special plants resistant to disease in a crop otherwise infested is particularly worth while. In very many cases it is the chance discovery of a resistant plant which has led to the introduction of a new variety: in this way it is always possible for the farmer to co-operate with the scientist for the good of agriculture as a whole.

CHAPTER VI

SUSCEPTIBILITY AND RESISTANCE TO DISEASE

ONE of the most marked features of cultivated plants is the difference in susceptibility to disease, as between different varieties. Nearly all crops have been in cultivation for long ages, and practically all exist in innumerable varieties which are inherently different in certain characters, including reaction to pests and diseases. For instance, "Great Scot" potatoes are immune from wart disease but susceptible to blight, while the variety "President" is susceptible to wart disease but markedly resistant to blight.

Generally speaking, the susceptibility of a particular variety to a certain disease is dependent upon the relation of its constitution to local conditions of weather and soil. The degree of susceptibility therefore is modifiable, within limits, according to the season, although in wart disease of potatoes there is an exception to this general rule in that a variety of potato which is immune from this disease remains immune under all field conditions. In consequence of the

almost universal seasonal changes new varieties of crop plants are—or ought to be—tested for several years as regards reaction to disease, as well as regards yield and other characters, before being placed on the market. In consequence too of the effect of different environmental conditions operating in different areas, the same variety may show considerable variations in susceptibility from place to place in the same season, so that in this respect also the "local adaptation" of varieties is a factor of great importance.

Plant breeders nowadays devote special attention to the raising of new varieties more resistant to disease than those previously in use. This is often done by deliberately combining the resistant character of one parent with some desirable quality in the other parent—*e.g.* heavy cropping capacity—for the plant breeder knows that, according to the laws of heredity, there may appear in subsequent generations of the hybrid thus created plants which possess both sets of desirable qualities. These are bred from again, and in this way new and improved types are created and preserved.

Professor Sir Rowland Biffen was the first person to show that the characters of susceptibility and resistance to a specific disease were transmitted from generation to generation in accordance with Mendel's law of heredity. He demonstrated this by tracing the reaction to yellow rust of the descendants of a hybrid wheat produced by crossing a susceptible with a resistant variety. In this way he was able to combine the quality of resistance to yellow rust with other desirable qualities. Many such varieties have now been produced, one of the best known being "Little Joss."

With potatoes, immunity and susceptibility to wart disease are strictly hereditary characters, and the potato breeders have this fact to guide them. With potato blight the problem of breeding for disease-resistance is more complicated. Although a few varieties, like "President," are markedly resistant to blight, it is particularly difficult to combine this character with certain other desirable characters, such as the high culinary quality of the varieties "King Edward" and "Up-to-date."

Plant breeders are now tackling many other

important disease problems along similar lines. Bunt is one of the chief scourges of wheat, and if varieties very resistant to it could be introduced into cultivation the gain would be considerable. In America some varieties of wheat are very resistant to it, and if the resistance holds good here, these varieties may be useful in building up commercial kinds which will be practically free from this serious trouble. The chief disease of barley in this country is "leaf-stripe," which is very difficult to combat directly. Here again the best means of control would be the production of varieties more resistant to it than those now in use. Attempts are being made to achieve this.

The plant breeder sometimes uses unexpected characters in attempting to build up varieties less liable to disease. For instance, a variety which grows particularly rapidly during the stage of development when it is susceptible to disease will be less seriously attacked than one which grows slowly through that stage. Early maturity of the crop may enable it entirely to escape disease which would attack it if the harvest were delayed. Early potatoes are

frequently not attacked by blight because they are usually lifted before the blight fungus is prevalent. The smaller amount of damage now caused by black or stem rust of wheat (*Puccinia graminis*) may be partly attributable to the use of varieties which mature earlier than those of former times, for if the wheat is nearly ripe before the fungus appears, little harm is done. If black rust again threatened to become serious, attempts would certainly be made to obtain varieties which would ripen even earlier than those now in use.

In the case of insects it is not possible to instance any such striking cases of immunity and susceptibility in different varieties of the same crop as is shown, for example, by potatoes to wart disease. In the following pages notes will be found upon such crops as winter- and spring-sown beans or winter- and spring-sown oats which differ markedly in the extent to which they suffer from black aphis and frit fly respectively, but these are hardly true cases of varietal resistance, for the susceptibility or resistance is due solely to the fact that one crop is less advanced in growth than the other. If,

for instance, winter-sown and spring-sown oats reach the same stage of growth when the frit flies appear, then it is most likely that they will suffer injury to about the same extent. There are, however, certain cases in which genuine susceptibility or resistance is at least suggested. For example, the potato "Golden Wonder," when grown in the field with other varieties, almost always suffers more from wireworms and slugs, possibly because the sugar-content of the tubers is high. Again, in the few attacks of Hessian fly recently reported, the wheat "Sensation" is the variety concerned. It would appear that the varieties more usually grown are less susceptible to this pest.

Differences such as these, however, are more tantalizing than helpful to the practical man, for it is exceedingly difficult to profit by them commercially. There are no clear-cut distinctions upon which the plant breeder can work, and although theoretically the proper method of avoiding damage by pests is to grow resistant varieties, in practice it is seldom possible to do more than eliminate varieties which prove specially susceptible to a particular pest in a

particular area. A variety in a certain locality is found "not to pay," and no matter whether this is due to special liability to insect attack or to unsuitability to the district in other ways, it drops out of cultivation automatically, often without the real reason being detected.

So far as insect pests and varietal resistance are concerned, the position is not very hopeful —quite the reverse to what it is in regard to fungi, or, indeed, to insects and horticultural plants.

CHAPTER VII

SEED

THE necessity of using seed of high quality has been emphasized by the passing of the Seeds Act of 1920, which compels seed merchants to declare the percentage germination and purity of the seeds they sell. The Act, by eliminating low-quality seed, tends to ensure freedom from pests and diseases to some extent, but does not offer a complete safeguard in this respect. To obtain reasonable security against pests and diseases, seed of the highest quality only should be purchased. Although this is somewhat more expensive than second-grade seed, the use of it is sound economy in the long run.

Seeds frequently bear either within or upon their coats the germs of fungus diseases, which are detectable only with difficulty. In fact, where the disease is within the seed, its presence sometimes cannot be ascertained until long after germination, or can be established only by methods much too difficult for general application. On the other hand, the germs of disease which lurk on the surface of the seed, such as

bunt in wheat, or celery blight, can often be demonstrated by examination under a microscope. The farmer, however, has neither the time nor the facilities to make the tests himself. He can, however, on payment of a small fee, ascertain from the Official Seed Testing Stations of England and Scotland whether his seed wheat is affected by bunt, or whether his celery seed is contaminated by the celery blight fungus. Otherwise, apart from certain supplementary measures, to be mentioned later, which he can take, he is chiefly dependent on the good faith of the seed merchant and the person who grows the seed.

Growing crops for seed is an art in itself, and owing to climatic and soil limitations this is best done in certain parts of the country—*e.g.* Northern or Highland districts for potatoes and the Eastern Counties for several other crops; much of the seed used in this country, however, is raised abroad. It is clearly important that any crop which is going to be used for seed purposes should be true to varietal type and as free as possible from disease. In some crops, notably potatoes, roguing is carried

on during the growing season to ensure trueness to type, and in lesser degree freedom from "degeneration" diseases. Bunt and smut diseases of wheat and other cereals would be entirely eliminated if care were taken to obtain seed from fields entirely free from these diseases and to thrash the grain in machines uncontaminated by the spores of these fungi. This unfortunately does not happen in present practice, and every year many samples of cereals are found to be contaminated by smut fungi. In view of the risk of seed wheat in particular being affected in this way, the farmer is well advised to "dress" or "pickle" his grain with a fungicide before sowing, according to the instructions given on page 90. Somewhat similar treatment of seed, in order to destroy dangerous fungi, is advisable also in other crops.

In the past certain destructive fungi have been introduced into the country by the purchase of contaminated plants and seed from abroad. In consequence of this, legislation has been enacted in recent years to control plant imports so as to prevent as far as possible the further introduction of harmful pests.

It is in the case of the potato crop that the use of first-quality seed is most essential, and by "seed" here is meant of course the use of seed tubers. As will be related subsequently, potatoes in many parts of England, especially in the south, readily fall a prey to infectious and so-called "degeneration" diseases, so that home-saved seed in these parts gives a greatly diminished crop, especially after the second season from Scotland or Ireland. These degeneration diseases are less frequent in some parts of Scotland, and it is chiefly in consequence of their greater freedom from these troubles that Scottish seed usually gives much heavier crops than home-saved seed in most parts of England. Seed potatoes once-grown in England, particularly in Lincolnshire and Cambridgeshire, but originally from Scotland, often give good yields, but it is extremely hazardous in the south to save seed for more than a single season. Many potato growers obtain their seed fresh from Scotland every year. In Holland extraordinary care is taken by the growers in saving seed to eliminate any potato plants that show the slightest signs of infectious "degeneration" diseases.

Fortunately at the present time the careful practice of the best Scottish growers maintains a high standard of vigour, but the day may come when growers of this crop in the south may have to take the same precautions as the Dutch growers to ensure sound and vigorous seed.

When considering insect or animal pests, good seed is equally desirable, chiefly because by germinating rapidly and well it will soon produce a good "plant." There are, however, one or two pests connected with the seed which deserve brief mention here. Seed beans for instance not infrequently contain bean beetles (*Bruchus rufimanus*), which in the grub stage feed within the bean. These beetles leave the bean by a neat, circular hole, which is very characteristic. It is better to avoid using for seed samples which show signs of beetle attack, for, although the damage seldom prevents the seed from germinating, injured seeds not only contain less food for the young bean plant, but also are very apt to be chosen by such soil pests as millipedes, which enter easily through the hole made by the beetle. Seed peas also may be attacked by similar beetles, and are also rather liable to be

damaged by the caterpillars of the pea moth. In either case damaged samples should be refused for sowing.

Finally, reference may be made to the wheat eelworm—the cause of "ear cockles"—which is not often, and ought never to be, a serious pest. Ear cockles are little black bodies about the size of, and somewhat resembling, a wheat grain in shape, though more nearly spherical. These "ear cockles" are packed with young eelworms, and if they are sown with the wheat the cockles swell and burst, and the little eelworms work their way to a wheat plant and penetrate it. They often cause some slight damage to the plant, as for instance by producing a crinkling of the leaves; but this usually passes unnoticed, and it is not until harvest that the ears are found to contain not only wheat kernels but also a proportion of "ear cockles" which have taken the place of kernels in the ear, thus reducing both the yield and quality of the sample on thrashing. The wheat eelworm does not seem to persist in the soil and therefore the remedy is obvious—viz. never to sow a sample of wheat containing ear cockles. If necessary,

methods can be used for floating out the cockles from the wheat, but with so much good seed wheat available the treatment is waste of time. Cockled wheat should be regarded as altogether useless for seed purposes.

There is one dangerous parasitic flowering plant the seeds of which are often found in samples of clover seed: this is dodder, which is very destructive. The Seeds Act provides that clover seed must be tested for purity at an Official Seed Testing Station. All samples found to contain dodder should be rejected until completely cleaned of the contamination.

CHAPTER VIII

SOIL AND SOIL PESTS

THE soils of this country show great diversity in their physical and chemical constitutions. These differences exercise an enormous influence upon the growth of crop plants, and the farmer selects his crops to suit the particular soils upon his land. Where a crop grows most vigorously, there will it generally be most free from pests of various kinds. The farmer has long recognized this, and all his operations are planned and timed to promote the maximum vigour in development.

Drainage.—Adequate drainage of the soil is of fundamental importance in all kinds of farming, for if the soil be liable to become water-logged, or flooded, troubles innumerable will follow. Roots or other parts of the crop may become asphyxiated owing to lack of air in the sodden soil, nitrification will be greatly diminished, and, in the case of wetness which does not actually amount to water-logging, abundant opportunity may be afforded for infection by some soil pest. The least harmful

result of ineffective drainage will be a check in the growth of the crop until the superfluous water has been removed. Water-logging of the soil very commonly implies heavy rainfall, but there are many areas in this country which could unquestionably be improved by further drainage if it were financially worth while.

An excessively wet soil favours attack of roots and tubers by parasitic organisms in the soil. Finger-and-toe disease of turnips and powdery scab of potatoes are both favoured by unduly wet soil conditions, and crown-wart of lucerne usually occurs only in fields where the crop has been partly covered by water in the early spring. The latter disease is rare, and can be looked upon as an accident related to abnormal weather, but finger-and-toe of turnips and powdery scab of potatoes are of common occurrence, and in areas where these diseases are rife these crops should be grown on the relatively drier parts of the farm.

Effective drainage is also an important factor at harvest time, especially in the root crop. It is of advantage to be able to get on to the land as soon as the crop is ready to be gathered,

whereas, if the land be then sodden, there may be serious delay, resulting in deterioration of quality and loss from various kinds of rots.

Chemical Characteristics. — The chemical nature of the soil is as important as its physical texture. Even where the crop grows vigorously there may be some chemical condition of the soil which favours attack by a parasite. Sour soils—*i.e.* those which show an acid reaction—are notoriously liable to finger-and-toe disease of turnips and swedes. Most parasitic organisms are favoured in their development by certain specific conditions of acidity or alkalinity, and with this disease of turnips there is invariably associated a certain degree of soil sourness which facilitates attack by this parasite. It has long been known that a good dressing of lime, up to 4-5 tons per acre, is one of the most effective means of reducing this disease, the effect of the lime being to neutralize the sourness of the soil, thereby eliminating one of the conditions which favour the parasite.

There are other conditions of the soil, which, although at present obscure, are probably of a chemical nature, that sometimes render soils

unsuitable for the growth of certain crops, although otherwise such soils appear entirely suitable. On some alkaline soils oats are badly affected by the disease known as "grey leaf," which is not due to a parasite, but is clearly related to certain soil conditions. Oats grown on such soil inevitably become affected by "grey leaf," which checks the growth and greatly diminishes the yield. In this trouble the application of lime causes further aggravation, but additions of potash, superphosphate or manganese sulphate to such soils greatly reduce the disease.

Soil "Sickness."—In the case of some parasitic organisms that persist in the soil, land heavily infested by them is said to be "sick." Clover "sickness," whether caused by an eelworm (*Tylenchus dipsaci*) or by a fungus (*Sclerotinia trifoliorum*)—although the latter disease is preferably called clover rot—often prevents clover from being grown more frequently in the rotation than once in eight years, the land being said to be "sick" to clover in consequence probably of the persistence therein of the disease-producing organism. In the cultivation of flax,

"sickness" of the soil is due to a parasitic fungus that continues to live in the soil.

The usual method of dealing with soil "sickness" of this type is to extend the rotation so that by the time the susceptible crop is grown again the destructive organisms are greatly reduced in numbers or entirely absent, in consequence of lack of suitable hosts during the intervening period. Partial sterilization of the soil to eliminate "sickness" of various kinds, either by the use of steam or antiseptics, is very rarely commercially feasible under outdoor conditions, although great benefit accrues from it in certain cultivations under glass.

"Early" and "Late" Soils.—Some soils are earlier in character than others—*i.e.* the seed bed can be prepared upon them earlier than upon other soils, and at the same time they become warm more rapidly after the winter cold is over. Such early soils are in great request for horticultural purposes, because the crops mature more rapidly upon them. In certain kinds of agriculture early soils are distinctly advantageous, as upon them varieties can be grown which will mature before certain

diseases become prevalent. For instance, second-early varieties of potatoes can sometimes be harvested on favourable soils before the blight fungus has begun to spread seriously.

Manuring.—Manurial treatment of the soil has a direct bearing upon the liability of crop plants to disease. The object of manuring the soil is to increase its fertility so as to obtain the maximum yield per acre. It is a matter of common knowledge that different crops react differently to specific manures and that the same manure applied to different soils may have diverse effects. Potatoes respond particularly to potash manures, and turnips to phosphates, while a sufficiency of available nitrogen during the early growth of wheat is essential. Whereas a certain minimum supply of nitrogen is necessary for all crops, nitrogen supplied in excess delays ripening and tends to cause a succulent or tender type of growth which is particularly susceptible to fungus attack. Rust and mildew in wheat are liable to be more prevalent if the soil contains nitrogen in excess. Light dressings of nitrate of soda in the spring to certain cereal crops may enable these to "grow away" from

some insect and fungus attacks. The addition of potash manures, and to a lesser extent phosphates, tends to increase resistance to fungal invasion. Phosphates also promote early ripening. It is essential that a proper balance should be maintained in the application of manures if the maximum yield is to be obtained. The effect of lime as a means of correcting soil sourness has already been referred to, but excessive applications of lime may result in other troubles, such as common scab of potatoes.

Common Soil Insect Pests.—No matter what soil a farm may be on, it is certain that soil pests as a class will prove troublesome and destructive, for not only are such pests exceptionally difficult to destroy, but also in most cases they have a very wide range in taste, and attack the roots of more than one kind of crop. For this latter reason it is convenient to devote some attention here to soil insects in order to avoid repeating the same information in each of the chapters devoted to the more important crops.

It is of course impossible to deal with all conditions of soil and all the soil pests which may be found in them, but probably something

like nine-tenths of the damage of commercial importance is due to one or other of the following: wireworms, leather-jackets, cutworms, chafer grubs, slugs and eelworms. According to the season these pests may be found in practically every class of soil, but as a rough generalization it may be taken that wireworms, cutworms and chafer grubs occur in greater abundance on soils which are light and well drained, while leather-jackets require moist conditions, and slugs prefer land which is both heavy and wet. Such small changes, however, as can usually be made in soil texture by cultivation are not sufficient to render a soil actually unsuitable to any of these pests, and in consequence means of checking them must be sought along other lines.

Wireworms, as the most troublesome of all, may be considered first. Here the dominant considerations are: (1) that the female Click Beetle, the parent of the wireworm, lays her eggs for choice in grass-land, though she seems quite prepared to accept a weedy crop as a substitute; (2) that the wireworm itself lives for at least four, probably five, and possibly six years in the wireworm condition before

changing into the chrysalis, from which the click beetle ultimately appears. If, therefore, a piece of grass or seeds mixture be ploughed after it has been down for five years, there may be five generations of wireworms in the turf, ranging from worms of only a few months old upwards. It will therefore be five years before that land becomes clear of wireworms, though each year of cultivation will see their numbers reduced as the worms become full fed and turn to beetles. Exactly the same applies to foul land, which may be cleaned of weeds but will still suffer from wireworm attack for several years. Reverting again to the grass field or ley, the ploughed-in turf will remain in sufficiently good condition for the wireworms to eat for some time after ploughing, and if, therefore, the new crop is sown fairly soon after, it may well escape the pests, which continue to feed upon the turf. As the latter decays, the wireworms are forced to look elsewhere for food; this explains why wireworm attack is usually so much worse the second year after ploughing than the first.

Although grass roots and young shoots appear

to be the natural food for wireworms, when the insects are deprived of this food they will feed upon practically every crop and most weeds, flax alone perhaps being immune; they will also eat small grubs, earthworms and even other wireworms. Apart from this varied diet, they can also resist starvation for long periods. One of the writers was once sent two wireworms in a tomato stem enclosed in a small tin; the tin was overlooked for exactly a year and the wireworms were then found to be still alive and apparently *little the worse! Death as a* result of sheer lack of food, therefore, can seldom overtake the wireworm, but this does not imply that they thrive equally upon all foods. White mustard, for instance, they will eat—may even damage considerably—but they certainly do not succeed in a field sown with this crop, even when it is taken for seed and not ploughed in. The reason for this is not known: it may be due to the mustard oils liberated in the soil, mustard oil being very poisonous to wireworms, or feeding upon mustard may cause them "indigestion"; at any rate mustard is an excellent crop for sowing upon

infested land. Of other crops useful in the case of infested fields, beans may be mentioned, for though they have been wiped out occasionally by wireworms, more often they succeed. The cereals are, of course, all liable to injury, but rye is decidedly resistant to the pests, while it is sometimes possible to take a late-sown crop of barley on land moderately infested, probably because the barley grows very rapidly if weather conditions are favourable, and so remains for only a short time in the young stages susceptible to attack.

More could be written about wireworms if space permitted, but in leaving them it may be interesting to point out that, judged by their relatives in the insect world, wireworms ought not to have become farm pests, since the larvæ of most click beetles are hunting insects, feeding upon grubs, worms, etc. Even now they retain some of their better instincts, and one of us has on several occasions found them in the act of devouring the maggots of the wheat bulb-fly. It is a pity the race as a whole cannot be converted: this would form the finest remedy for soil pests imaginable!

Leather-Jackets.—As soil pests, leather-jackets (which are the young or grub stage of the Daddy Longlegs fly) are probably next to, though far behind, the wireworm in destructiveness. Like the click beetle, the female Daddy Longlegs (or crane fly) prefers to lay her eggs in grass fields and clover leys, but, unlike the wireworm, the leather-jacket lives for about nine months only before turning into a chrysalis. An arable field therefore ought not to be infested for more than one season at a time, unless it is down to ley; and it also follows from the egg-laying habits of the fly that the crops most likely to suffer are those which in the rotation follow the clover or seeds course—*i.e.* in the Northumberland rotation, oats, and in most other rotations, wheat. Wheat, however, suffers less frequently than oats, perhaps for the following reason. Crane-fly eggs are laid in July, August and September, perhaps the majority in the two latter months: the eggs soon hatch into little leather-jackets, which when young are very susceptible to drought and other unfavourable conditions. Leys to be broken for wheat will probably be ploughed

soon after harvest, when the leather-jackets are still young and likely to suffer if exposed to the normally dry air of early autumn. On the other hand, grass or clover leys to be followed by oats are usually ploughed in winter, when not only is the soil moist but also the leather-jackets are bigger and more capable of withstanding unfavourable conditions. Oats, therefore, are naturally more subject to leather-jacket attack than the wheat crop, but the latter may also suffer in a wet autumn—when the young insects will be little injured in the ploughing and other operations preparatory to sowing wheat.

As regards remedies, the obvious though unpalatable suggestion is to plough before August and sacrifice whatever keep or aftermath might be produced. This method is certainly the correct one when the land is to be devoted to market-garden crops, but it does not find favour with farmers; from which it might reasonably be deduced that money loss by leather-jackets on the average does not equal the value of the aftermath or grazing from August onwards. However this may be, there is no question that in years in which leather-

jackets are numerous, the demand for a remedy if it existed, even at the rate of £2 or £3 an acre, would be very considerable.

In this connexion it may be of interest to mention that moist bran is readily eaten by the pests when they come to the surface at night, and therefore if such bran be rendered poisonous a considerable proportion of the leather-jackets are killed. So far as the leather-jackets are concerned, Paris green answers the purpose, but there is the possibility — though it is certainly remote—that poultry and birds might discover the poisoned mixture, and suffer. (The mixture consists of 20–30 lb. bran, moistened with water, plus 1 lb. Paris green, to the acre.) The discovery of an alternative poison less harmful than Paris green to birds would go far to solve the problem. As matters stand, it is possible that the use of Paris green and bran might prove to be illegal in England and Wales.

In leaving leather-jackets, one other method of dealing with this pest may be mentioned, as it applies chiefly where the insects are damaging low-lying grass-land. It consists in the use of the "Grippel wheel," a Dutch invention, which

can be attached to a farm cart and which cuts a deep, narrow furrow or grip 6-8 inches deep and 2 or 3 inches wide, each furrow being about 6 feet from the next. The leather-jackets in travelling about in the turf fall into the furrow and, being unable to get out, die. It is reported, however, that the Dutch are abandoning this method for the poisoned-bran bait mentioned above.

Cutworms or *Surface Caterpillars*, distinguished from the preceding by the fact that they have legs, every now and again are responsible for very heavy losses to root and potato crops during the latter half of the summer, and they often take toll of winter cereals as well, though the losses here are seldom so obvious. The moths which lay the eggs from which cutworms are hatched appear in the latter half of June, the Turnip Moth being one of the most common. If the weather in July is favourable to the young caterpillars (apparently when that month is hot and dry) they grow very rapidly, eat ravenously, and may reduce fields of mangolds, turnips or even potatoes to half a crop before the end of August, when these rapid growers

turn to chrysalides, from which moths appear in September and October and lay eggs for a new generation. Ordinarily, however, only a small proportion of the summer caterpillars behave in this manner; the majority grow more slowly, feed on through the autumn and winter (when they damage cereals) and turn to chrysalides in spring—at the same time as the "children" of the fast-growing members of their family. The moths from the two generations appear simultaneously about midsummer.

Cutworm epidemics are exceedingly puzzling from the farmer's standpoint, for it is clear that by no cultural measures can the attacks be avoided, while remedial measures are not much more easy to plan. The bran and Paris green bait, as used for leather-jackets, is fairly effective in the case of root crops, but is not of much use with potatoes, while its disadvantages have been made clear. Apart from this, however, the only treatment at all practicable is to turn poultry into the infested fields (especially roots), if possible confining the birds for several days to a definite area and then moving them on

when their scratching appears to be damaging the crops. In the 1922 epidemic considerable success was obtained on some farms by this method, and as the poultry were reported to have thrived amazingly on a liberal caterpillar diet, it has at all events the advantage of making the best use of a pest!

Chafer Beetles are perhaps hardly worth mentioning in the same category as the above pests, but a brief reference to them seems necessary, as those who have had good pasture ruined by chafer grubs may well realize. Three species are fairly abundant—the cock chafer and the smaller summer and garden chafers; in each case the grubs feed upon the roots of the turf, the affected patches becoming brown in colour and soft and spongy to the tread. There is no very certain remedy, though of course the affected turf should be rolled down and dressed with a manure to assist its recovery. Two interesting experiments may be mentioned. In the first a steam-roller was "persuaded" to roll down the affected areas in a valuable field, with completely satisfactory results, the grubs being squashed. In the

second the affected areas were dressed with semi-refined naphthalene at the rate of 5 cwt. per acre, again with strikingly successful results —so much so that three months after application the previously affected patches were remarkable, not for their brown colour, but for the brilliant green of the fresh young grass. It is disappointing, however, to have to admit that this result cannot be repeated regularly, and that the conditions under which naphthalene is effective are still unknown, though from the range of experiments which have now been carried out it is clear that suitable conditions for the use of this chemical are rather seldom found.

Slugs and *Eelworms*, though partly soil pests, are best treated in connexion with the crops they damage rather than in a chapter on soil pests. One point in connexion with eelworms is perhaps better dealt with here, and that is: how long can eelworms persist in the soil of a field in which crops not suitable to them are grown—*i.e.* if one kind of crop is attacked, how long a period must elapse before it is safe to sow the same or another susceptible crop on

the same field? In this connexion it is necessary to point out that there are two types of eelworm commonly found attacking farm crops. One is the Stem Eelworm type—the kind which attacks clover, causes tulip root of oats, and "bloat" of onions—and the second, the Beet Eelworm type, which attacks, in addition to beet, potatoes, peas and sometimes oats. Owing to the great range of plants attacked by the stem eelworm, or varieties of it, it is difficult to obtain definite evidence as to how long the pest has persisted in the soil, since it may have been enabled to live unnoticed upon some crop which showed little sign of attack. In regard to the beet eelworm the case is rather different, for this eelworm differs from the stem eelworm in that its eggs are not "laid," but remain within the mother worm, which swells into a minute body something like a pear in shape. She then dies, and her skin forms a hard brown case surrounding the eggs, which, protected in this manner, can remain alive for long periods in the soil. A certain proportion of these eggs hatch each year, but investigators on the Continent have proved that some of them may remain

alive and unhatched even for six years, and perhaps longer. Of course, after six years, only quite a small proportion of the eggs remain to be hatched, and the resulting worms are not likely to cause a severe attack; but it is clear that for the complete eradication of the worms a very long period between susceptible crops—probably something like ten years—is required, although for practical purposes five years should be sufficient.

Soil Insecticides.—Undoubtedly the greatest need at the present time is for a reliable soil insecticide which can be applied like an artificial manure and which will destroy pests in the soil, but it can be stated definitely that the ideal substance has not yet been discovered. One of the writers would go further, and say that nothing even partially satisfactory for use under farm conditions is known, since that is undoubtedly his experience, but others have perhaps been more fortunate and so hold different views. There are quite a number of well-known soil insecticides of proprietary brands, but clearly it is impossible to do justice to them within the scope of such a book as this: all that can be

said is that most of them depend for their action on naphthalene, cresols, and other coal-tar products—chemicals which can be shown under laboratory conditions to be toxic to wireworms and other soil pests. Unfortunately their action in the field is not consistent unless the dressings applied are so large as to be quite uneconomic, apparently because light dressings (2-3 cwt. per acre) are rapidly broken down by soil organisms (bacteria) before the chemicals have had time to exercise much destructive action on insect pests. Even where this breaking down of the chemicals does not take place, there is great difficulty in mixing them sufficiently thoroughly with the soil. As has been pointed out, a dressing of even 4 cwt. to the acre gives only 1 part of the chemical to about every 4000 parts of the top six inches of soil, and thus it will readily be understood that soil pests have an excellent chance of escaping from the toxic substance, even if the latter is fairly persistent. The position at present, therefore, is not very hopeful, but it is certainly not hopeless, for there are a vast number of chemicals still uninvestigated. Until some outstanding dis-

covery is made, farmers will probably do well to test soil insecticides on small acreages without risking too great an expense: until they have proved to their own satisfaction that some chemical is effective they should rely rather upon cultural measures to keep in check the ever-present population of soil pests.

CHAPTER IX

CEREALS

However unsatisfactory they may be from the economic aspect, the cereal crops, taken as a whole, form the keystone to arable farming in this country, and in consequence the pests and diseases which attack them are of special importance.

A. FUNGUS DISEASES

Bunt (Stinking Smut).—The most important disease of cereals at present in this country is bunt, or stinking smut, of wheat, caused by the fungus *Tilletia tritici.* The effect of this disease is to transform the grain into a mass of blackish spores having a fish-like odour, all the grains in the ear being usually affected. The disease is not conspicuous in the ripe crop, because the spore masses are covered by the unaffected chaff; but to the practised eye a bunted ear can be picked out from a healthy one, because the spikelets stand out at a wider angle. At the time of thrashing the bunted grains become conspicuous, and, owing

to the rupture of many of them, healthy grains become dusted with the spores, and the thrashing-machine also becomes contaminated. Where there is a large percentage of bunt in the grain the healthy grains may become superficially blackish in consequence of the spores deposited upon them. Millers object to buying conspicuously bunted samples of wheat, even though the spores can be washed off the grain. Very badly bunted samples can sometimes be sold only as inferior chicken-food. Grain so heavily coated with bunt spores as to cause it to be discoloured would not, of course, be sold for seed; but even a slight contamination of the grain, invisible to the eye, is sufficient to cause a serious degree of infection in the succeeding crop. In 1921-1922, 41 per cent. of the samples of wheat sent to the National Institute of Agricultural Botany for germination tests were found to be contaminated with bunt spores.[1]

Bunt can be avoided by ensuring that the seed grain is obtained from a crop free from the disease and thrashed in a machine that has not previously dealt with a diseased crop, but

[1] *Journal of the National Institute of Agricultural Botany*, No. 1.

this is only rarely possible. Bunt is such a generally distributed disease that the only safe course is to "pickle" or "dress" the grain with a fungicide, which has the effect of killing any spores there may be lurking on the surface, without injuring the germinative capacity of the grain. Many substances have been used in the past to kill the bunt spores on the surface of the grain, but at present a weak solution of formalin or of blue-stone (sulphate of copper) is in most common use. Either of these substances can be sprinkled over the grain laid out on the barn floor, or, alternatively, the grain can be steeped in the solution. Formalin has given the best results, and therefore the method of using it will be described, copper sulphate having been found to reduce the germination slightly.

Formalin for dressing wheat should be prepared by diluting 1 pint of the commercial formalin as bought (40 per cent. pure) in 40 gallons of water (or 1 fluid ounce in 2 gallons). The wheat is then spread out on the barn floor, and the weak formalin is carefully sprinkled over the heap at the rate of

about $1\frac{1}{2}$ gallon to the sack of dry wheat. The heap is then turned over several times until the grains are completely wetted and all the liquid absorbed by the wheat. The heap should now be covered for four hours with sacks which have been moistened previously with the dilute formalin. The heap is then uncovered and spread on the floor overnight to dry. The grain is ready for sowing next day. Alternatively, the grain may be immersed or steeped for a few moments in the weak formalin, spread on the floor, covered with sacks for four hours, and allowed to dry as before. Dressing wheat with formalin by either of these methods costs less than sixpence a sack, and is practically a complete insurance against bunt.

The grain is sometimes dusted with a fungicidal powder instead of steeping or sprinkling it. In some countries, notably Australia and the United States, the grain is often dusted with copper carbonate at the rate of 2 oz. to the bushel. The grain may be dusted a considerable time before sowing, or could be purchased with advantage in an already "dusted" condition. In treatment of bunt by

dusting with a fungicide it is essential that the powder should be in an extremely finely divided form and that it should be evenly distributed over the grain by a proper dusting machine. The advantage of sprinkling the grain with formalin is that no special machine is required.

Infection of wheat by the bunt fungus takes place only in the seedling condition, in which the fungus after entry soon passes to the growing apex of the plant, usually keeping pace with the growth of the latter until the ear is formed, when the fungus grows out into the developing grains, transforming them in the manner already described. Many farmers believe that if there is bad growing weather in spring, the wheat is particularly liable to be bunted if the grain has not been dressed. Although this has not yet been scientifically proved, there are reasons for thinking that when wheat grows well in spring, the fungus does not always keep pace in its growth with the wheat, with the result that the fungus gets left behind and the ears remain unaffected at harvest. Anything, therefore, that will facilitate rapid growth of the wheat in the spring should be done—such, *e.g.*, as

the application of a light dressing of nitrate of soda.

Different varieties of wheat show varying degrees of susceptibility to bunt, and, in general, autumn-sown wheat is more affected by it than is spring-sown. Work in the United States indicates that there is some possibility of breeding, in the future, types of wheat either resistant to or completely immune from bunt.

Other Smuts.—The smuts of wheat, barley and oats affect the ears in much the same way as does bunt, but more conspicuously, the black spore masses which replace the grains being clearly visible. In some of these diseases—viz. the loose smuts of wheat and barley, and also the oat smuts—the black spores are blown about freely by the wind upon emergence of the affected ears, leaving ultimately the bare stalks; but in the covered smut of barley the spores remain covered by a delicate skin until the time of thrashing. The oat smuts and covered smut of barley can be controlled by dressing the seed grain with formalin, as in the case of bunt, but the loose smuts of wheat and barley cannot always be so destroyed, as the fungus may be

already *within* the seed. Fortunately, the loose smuts of wheat and barley are not so common in this country as formerly, probably in consequence of the greater care now taken in choosing seed grain only from healthy crops, but covered smut of barley is still frequently seen.

Rusts.—In the past, black rust of cereals, especially wheat, caused by the fungus *Puccinia graminis*, caused grave damage in this country, as indicated by the agricultural writers of the eighteenth century; but at present the fungus is somewhat rare on cereals here, although its devastating influence is still the serious concern of farmers in North America, Australia and South Africa. In recent years the only areas in this country where it has been very harmful are Pembrokeshire (on wheat and oats) and a few places in Scotland (on oats). In all other grain-growing parts of the country the fungus either does not occur or infects cereals too late to do appreciable harm. In a country like Great Britain the intervention of barberry bushes appears to be necessary to allow of the continued existence of black rust. Long before the rôle of the barberry in the development of black

rust was scientifically proved, farmers had more than a suspicion that in some way the barberry favoured this rust; probably in consequence of this, barberry bushes were extirpated from the vicinity of arable land, thus reducing enormously the capacity of this fungus for doing harm. Where black rust is still prevalent in this country, barberry bushes are usually extensively found, and the fungus passes regularly from the straw or stubble of wheat and oats to the barberry in spring and back again from the barberry to the cereal plant in summer. Black rust affects chiefly the straw, producing thereon long black lines of spores. If the crop is affected at a critical stage in its development—before the filling of the grain—grave damage is done, resulting sometimes in the diminution of the yield by one half, as not uncommonly occurs in certain parts of North America. In parts of Great Britain where this fungus is still a serious pest, barberry bushes should be ruthlessly eradicated. It is of interest that the form of the fungus on wheat is slightly different from that on oats, there being usually no mutual infection between the two. Black

rust is undoubtedly the most serious fungus that attacks wheat, and it is a fortunate circumstance that it occurs so comparatively rarely in this country. In warmer countries—*e.g.* Australia—the intervention of the barberry is not essential for the continued existence of this rust.

The commonest rust of wheat in this country is yellow rust, caused by the fungus *Puccinia glumarum*, which is far less serious as a disease than black rust. Yellow rust is of almost universal occurrence on wheat in this country during the early summer, being present in the form of small yellow spots on the leaves, and sometimes on the stems and ears. It is much more abundant on some varieties than on others. Although yellow rust has no very serious effect upon the growth of most kinds of wheat it withdraws a steady, if slight, stream of food, which has the effect of reducing the yield, chiefly through some of the grains becoming shrivelled. The annual loss of yield in this country due to yellow rust probably amounts on an average to 5 per cent. With some varieties of wheat the loss is appreciably greater. Unlike black rust, this fungus passes its entire

life on cereals. Some years ago Professor Sir Rowland Biffen showed that if a wheat susceptible to yellow rust were crossed with one resistant to it, susceptibility and resistance to this fungus were transmitted to the hybrids according to Mendel's well-known law of heredity. Taking advantage of this discovery, new wheats have been built up which are more resistant to yellow rust than the varieties chiefly grown hitherto in this country, and, in consonance with this behaviour, of heavier cropping capacity. "Little Joss" is one of these varieties which is now in favour in many parts of the country. Yellow rust is of rare occurrence on barley, and is of no importance in this crop.

There is still a third rust of wheat of common occurrence in this country, characterized by the presence of brown pustules on the leaves, and known therefore as brown rust. Caused by the fungus *Puccinia triticina*, it usually develops late in the growth of the wheat plant and causes little harm, although in some wheat-growing countries—*e.g.* the Argentine—it is serious.

The common rust of barley is a brown rust

(*Puccinia simplex*), but most varieties of barley are not seriously affected by it.

There is also another rust on oats caused by the fungus *Puccinia lolii*, which is sometimes present to such an extent in the west and northern parts of the country as to reduce the yield appreciably and to render the grain unfit for seed purposes. This fungus affects the stem as well as the leaves, but it can usually be easily distinguished from the black rust because of the lighter colour of the earliest spore stage, and because the black lines of spores ultimately formed in the straw are much shorter. This other rust of oats is called crown rust, and investigations are in progress to try to build up varieties which are highly resistant to it, although the fungus usually develops too late in many parts of the country to cause much harm. It is of interest that in crown rust of oats there is an alternation of the fungus from oats to buckthorn, similar to that occurring in black rust from oats to barberry. It is not yet known whether the stage of the crown rust fungus on buckthorn is absolutely necessary for the continued existence of the disease on

oats in this country, but, where crown rust of oats is at all severe, buckthorn bushes on the borders of arable land should be destroyed as a precautionary measure.

Mildew.—The white mildew caused by the fungus *Erysiphe graminis* is of common occurrence on the leaves and stems of cereals, especially some varieties of wheat. As the fungus gets older it becomes brownish in colour. It occasionally occurs on wheat ears, as in the variety Benefactor. How much damage this fungus causes it is very difficult to estimate, but where it occurs profusely on the lower parts of the stems—on which it is often overlooked—it may be a serious factor in "lodging" of the crop in wet weather before harvest, especially in the Fens. In the course of time, varieties of wheat more resistant to mildew than many now in common use will probably be introduced.

Leaf-Stripe.—Leaf-stripe of barley, due to *Helminthosporium gramineum*, is a more serious fungus than is generally supposed. The common symptoms associated with this disease are long brown stripes on the leaves and blindness of the ears, but the fungus may also be responsible

for killing young plants outright and for non-emergence of the ears. This is another of the diseases propagated primarily by means of the seed grain, which may become slightly invaded by the fungus while still in the ear, or which may carry on its surface the spores of the fungus. To some extent the disease can be controlled by dressing the seed before sowing with weak formalin (as described for treating bunt), but not entirely, as the fungus is sometimes just within the grain. Until varieties of barley have been built up which are particularly resistant to this disease, the utmost care should be exercised in taking seed only from crops entirely free from this fungus. Six-rowed barley is more susceptible than two-rowed barley, and, in the latter, winter sowing appears to favour the disease, especially in cold winters, like that of 1923-1924. There is a closely allied but less serious disease of oats, caused by *Helminthosporium avenæ*, in which young oat plants may be killed or their leaves affected by brown stripes.

Ergot.—In countries like Russia, and parts of Germany, where rye is grown on a large scale,

the ergot fungus, *Claviceps purpurea*, is found abundantly. Fortunately it is of rare occurrence on cereals and fodder grasses in this country, although common on some wild grasses. The ergot, which is one stage in the life of this fungus, is a hard, blackish body which replaces the grain and protrudes about half-an-inch or more from the ear; at thrashing it is liable to be included with the grain and may subsequently contaminate the flour. Ergot contains poisonous principles, and if flour containing more than a minute percentage of it is used for human consumption, serious diseases may result. Ergoted grain and grasses may cause abortion and other diseases in farm animals. This disease is propagated by ergots falling to the ground at harvest, where they remain dormant until next year's ears are appearing, when spores are produced which infect the flowers and subsequently transform the grain. Rivet wheat and rye in a few localities are the only kinds of cereals at all liable to attack by ergot in this country. In some parts of the Fens oats are grown after rye. Self-sown rye plants which come up in the oats are often ergoted although

the previous rye crop was free from the fungus.

Whiteheads or Take-all.—In recent years this disease has been reported on wheat in this country, and it is one against which farmers should be on their guard. It is not, however, nearly so serious here as in Australia and the United States, where a 30 per cent. loss is not uncommon. It may also attack other cereals. The popular names given to the disease refer to the white ears, containing no—or only shrivelled—grains, characteristic of affected plants if they grow to full stature. The base of the straw is discoloured and readily breaks. The disease is caused by the fungus *Ophiobolus cariceti*, the spores of which are formed in the lower part of the straw and which, ploughed in with the stubble, are liable to infect a succeeding cereal crop—*e.g.* oats. The fungus attacks couch and other grasses, so that for this reason also the land should be kept free from these weeds. At harvest it is advisable to avoid cutting too low, or the basal part of the straw, bearing spores, may ultimately find its way into the dung and so spread the disease to other fields.

The disease is most severe where there is no extended crop rotation.

B. INSECT PESTS

Some of these pests have already been dealt with in the chapter concerning the soil, and, fortunately, so far as insects are concerned, those that remain to be discussed are relatively few in number. Of course there are many kinds of insects which are minor pests of cereals, but apart from soil insects, such as wireworms and leather-jackets, most of the damage of commercial importance is caused by the following pests: wheat bulb fly, frit fly, gout fly, corn aphides, corn thrips and eelworm.

Winter Wheat.—In Britain winter wheat is as a rule a relatively safe crop so far as insect pests are concerned, and this is especially the case when, as usually occurs, the plant is well established before the new year. The vulnerable points of the wheat plant are the first young shoot and the underground stem above the roots; but as soon as the tillering stage is reached the destruction of the first shoot becomes of less importance, as the damage is

usually repaired by the production of fresh tillers.

Of the various pests mentioned previously, the first which is likely to cause damage is the *Frit Fly*, the wheat beginning to go off in late autumn and winter. The process is rather indefinite, and not always noticed: the young central shoot is killed by the frit maggot and the whole plant, if young, ceases to grow and dies without showing any of the usual signs of sickness, such as the yellow colour so frequent in, say, wireworm attack. Fortunately frit fly attack on winter wheat occurs only under certain circumstances—where a grass field, or more especially a rye-grass ley, is ploughed in autumn and is sown straightway with wheat. In such a case the frit flies of the last generation, which were active during the month of August, and perhaps September, have laid their eggs on the rye-grass, and the young maggots, upon hatching, have not found it possible to live for long upon the grass, which has by then been turned under by the plough. They have therefore worked their way up out of the sod and into the young wheat plants, with the results

previously mentioned. The remedy is, of course, obvious—to plough leys containing grass and intended for winter wheat before and not after harvest, even though this involves the sacrifice of the aftermath or some useful keep. According to the information at present available, damage to winter wheat by frit fly has been found chiefly in the eastern counties, but it probably occurs wherever winter wheat follows autumn-ploughed leys containing rye-grass.

The next serious damage to which winter wheat is liable is the combined attack by soil pests of all sorts during winter, resulting in what is sometimes known as *Winter Wasting*; this often turns a thick "plant" into a thin one, although it perhaps produces less effect on the ultimate yield than might be expected, owing to the capacity of a wheat plant to fill up and occupy the space which would have been taken by its neighbours if they had lived. The conditions shown by winter wasting are of course just those in which the crops will be benefited by a top-dressing, as indicated in Chapter VIII., especially where the soil has been leached by continuous rain.

One other pest which perhaps deserves special mention—the *Slug* (especially the Grey Field Slug)—may completely strip a wheat field of all green leaf during the winter. In such an attack as this anything which checks the slugs, even if only temporarily, will give the wheat a chance to persist. A dressing of ground quicklime, or lime freshly slaked to a powder (about 10 cwt. per acre), has been quite successful. The lime can be put on by a manure distributor, preferably in the late afternoon. One of the writers has heard of one farmer who applied the lime almost before daybreak in the morning and after sunset at night, and got most satisfactory results. Slugs work at night, and if the lime can be powdered over them they will be driven down or killed. In the case just mentioned the lime was practically unslaked, and it burned the wheat considerably, but the effect was not permanent, while no further damage from slugs occurred.[1]

After passing the winter successfully, the next hazard to the crop is caused by the *Wheat*

[1] A mixture consisting of 1 cwt. kainit with 5 lb. of finely-ground copper sulphate, sown broadcast at the rate of 3 cwt. per acre, has been used with success by the Agricultural Department, Leeds University.

Bulb Fly, which probably does not occur in all localities or all seasons. Here again the maggot burrows within the growing shoot, killing it, and often causing the death of the plant attacked. These maggots are hatched from eggs laid by the parent flies during the latter half of the previous summer, and at that time, of course, the flies cannot know which fields are to be sown with wheat; but their habit is to scatter their eggs on any land bare, or relatively bare, of crops; this of course gives them a fair chance of selecting the right fields. Thus bare fallow, early potatoes, or potatoes which do not "meet" in the rows, thin root crops, etc., all leave bare soil; and it is after such crops or fallows that wheat bulb fly is to be feared. Damage by this pest is, however, rather local —the Fens of East Anglia, parts of Lincolnshire and Yorkshire, Cheshire, and parts of Scotland—and in such districts the remedy is a change in the rotation, following potatoes by oats, for instance, instead of wheat. Where the attack has not been avoided by this means, rolling, if the weather conditions admit, does a great deal of good. The maggots are not

killed by the roller, but by March, when the damage is likely to show, the wheat tillers freely, and the roller makes the soil firm round the roots and allows natural recovery.

After the risks from the wheat bulb fly have passed, the crop is most unlikely to be destroyed, or even very seriously harmed, by any other insect pest except corn aphides and corn thrips, which are dealt with subsequently (pp. 118, 119).

Spring Wheat differs little from winter wheat. The date of sowing renders it more likely to suffer from wireworm attack, as it is not well established in the early spring, when such attacks are more severe. This, however, is partly compensated for by an increased rate of seeding. It is not sown under the conditions which bring about frit-fly attack in winter wheat; while, equally, it is not a crop which will ordinarily be sown after bare fallow or roots, and in consequence is seldom damaged by wheat bulb fly. It is not immune, however, from this pest, and one of the writers has seen a crop of French Marvel heavily attacked.

Oats.—Apart from such pests as wireworms, the two outstanding oat pests are *Frit Fly* and

Eelworm, and the two are not infrequently confused by farmers. Frit fly is certainly much the more harmful of the two, and indeed may fairly lay claim to being the most destructive agricultural pest in Britain. Probably an annual average reduction in the crop of spring oats by something like 20 per cent. would be a reasonable estimate of the loss caused by this insect, and this is apart from the fact that the growing of spring oats has been practically abandoned in parts of Britain owing to the risks of frit-fly attack. The whole story of the frit fly is too long to chronicle here, but, briefly, the insect has three generations in the year. During May the little black flies lay eggs upon the young spring oats, the eggs producing maggots which feed in the young oat shoot, causing its death. As soon as the first shoot is checked, new tillers grow, and, in a light infestation, may replace those that have been killed, but often these second tillers are also eaten out by the little white maggots, with the result that the plant either dies or becomes like a tuft of coarse grass, with perhaps one weakly ear. The first generation of flies, therefore, reduces

the number of ears produced in a field. That, however, is not all. The white maggots turn to brown "puparia" in June, and in July the latter produce adult frit flies. At that time the oat ears are out of the sheath and approaching the flowering period, and the flies lay eggs on the young "bells" in the ear. The resulting maggots feed upon the developing kernel, often leaving little signs of damage externally. If, however, the thrashed oat is cut in half, the kernel will be found to be either shrivelled up or reduced to powder, all the "flour" being destroyed. The second brood of flies thus destroys the value of the kernels, and therefore the oat crop has to withstand two crippling attacks in the year, so that it is not surprising that the loss is heavy. There is yet a third brood of flies which hatch from the oat grains; these flies, having no oats to attack, lay their eggs upon grasses, especially rye-grasses, upon which the resulting maggots feed during autumn and winter, and finally produce flies the following spring, to attack the spring oats. This third generation of frit maggots does little apparent harm to the grasses, but its presence is manifest

if the grass is ploughed and sown with wheat, when, as has been said previously, the maggots move to the latter and feed upon it.

The problem of controlling frit fly satisfactorily has not yet been solved. It is, however, clear that once the oat plant has reached a certain stage, which is approximately when the shoot has four leaves or more, it is not again very susceptible to attack until the ears leave the sheaths. Winter oats, therefore, which have a good start of the flies, suffer little from the first-brood attack, and the same applies to early sown spring oats; but the difficulty in many parts of England is to sow early, since weather and soil alike may render early sowing impossible. Rapid growth in the early stage is of course what is desirable, and here tilth is perhaps of most importance. A fine tilth seems to have the greatest effect in assisting speedy seedling growth, and this is apparently why oats on the blacklands of East Anglia hardly ever suffer from frit, the tilth being unusually perfect; although frit flies are present in number, the crop is almost always just ahead, and only the late-produced tillers are attacked.

Probably the chief hope for the future in connexion with frit fly is the production of a resistant variety of oat, and already claims have been made that one or other variety resists attack. Such claims are usually misleading, and prove, when checked by a critical trial, to be due to experimental errors which are very difficult to eliminate. It may, however, be stated with confidence that there are significant differences between certain varieties of oats in the extent to which they will stand up against frit attack: for instance, Goldfinder, under the most critical conditions, has proved less susceptible than Black Tartarian in Oxfordshire and Hertfordshire, but it is impossible to say yet that this difference is of commercial value. The fact, however, that differences do actually exist is decidedly hopeful for the future, and it implies that the plant-breeding stations have something upon which to base their efforts in breeding resistant varieties of oat. At present, as far as spring attack by frit is concerned, earliness is the great object, and if the question is asked as to "how early," the reply may be that the oats should have reached the "four-leaf"

stage (three leaves fully developed and one folded in the centre) by the middle of May. As regards the second-brood attack on the young grain, earliness again is the great need, for it would appear that very shortly after flowering the grain becomes unsuitable for the newly hatched maggot. In this connexion it may perhaps be questioned whether by suitable manuring early maturity may not be hastened, as, for instance, by seeing that a proper balance is kept between the phosphorus and nitrogen elements in the manure, especially of course in seeing that the latter are not too prominent.

Frit fly, it will be seen, is a rather dismal subject, and the second serious oat pest, *Stem Eelworm*, is little better, though it is not nearly so prevalent. The injury it causes is not unlike that of the attack of the first brood of the frit fly (on the young oat plant). There is the same production of swollen, stumpy tillers, but in the case of the eelworm the swelling is more bulbous and the colour of the plant is often a light green, sometimes streaked with yellow-green, sometimes with yellow. More characteristic, however, is the fact that the

young central leaf of a shoot in an attack of eelworm remains green, but in a case of frit fly *turns first yellow and then brown; further, in* the latter, a little white maggot can be found within the shoot, while in an oat attacked by eelworm nothing can be found without a microscope, as the eelworms are too small to be seen with the naked eye.

Eelworm attack may occur in the case of both winter and spring oats, and it is often very bad on the former. The origin of eelworm attack upon oats is usually obscure. Since the same worm causes one of the forms of "clover sickness" it might be thought that oats would suffer after a clover crop destroyed by eelworm, and *vice versa*, but this by no means always happens. A bad attack seems usually to occur suddenly, with little in the history of the land to imply that it was likely. Some, perhaps many, of these cases suggest that the eelworms are often present in small numbers in most agricultural land, and that they multiply rapidly when conditions are unusually favourable. There is, however, another possible, though improbable, explanation: this is that eelworms are carried in

the seed oats. Although the evidence for this theory is not conclusive, it is a wise precaution *not to save seed from a crop showing signs of* eelworm attack. Of remedies for the attack there are none; and probably few readers of this book will need reminding that if a crop of spring oats has failed, it is folly to sow winter oats on the same ground in the autumn: yet this has been done, and more than once, with the result that for two years in succession the fields in question were failures.

Barley.—Omitting winter varieties as not sufficiently widely grown to justify comment here, barley is usually the last sown of the three cereals, but, in consequence, it often meets with better growing conditions and establishes itself rapidly—which is the reason why late-sown barley will sometimes succeed on wireworm-infested land where oats have failed. It is not subject to wheat-bulb-fly attack when sown as a spring crop, and is useful either for patching or replacing wheat crops which have been damaged by this pest. It is subject to frit fly, but not to an appreciable extent, and therefore of the serious pests *Gout Fly* is the one of greatest

importance. The maggots of this fly—like those of the frit and wheat bulb flies—feed within the growing shoot, and if this takes place when the plant is quite young, growth upward is stopped, but the shoot for a time continues to grow in thickness, forming a short, thick stump perhaps 4 or 5 inches long. More frequently, however, the attack occurs rather later, when the plant measures 12 inches or more in height and the ear is already developing. Then the maggot burrows down the side of the ear while in the sheath, and the stem just below it, and a gouty, swollen appearance is again produced owing to the check in growth. According to the time of the attack and condition of the plant the ear may cease all further development and ultimately die, or it may succeed in growing out from the ensheathing leaves, with the signs of damage showing as a long scar down one side and reduction in the crop.

In any case, the maggot, when about one quarter of an inch in length, is full fed, and turns into a brown puparium, often to be found lying in the groove in the ear or in

the surrounding leaves. From the end of July onwards the gout fly itself emerges. As no barley is available it lays eggs chiefly on couch grass (twitch) and rarely (more frequently in the S.W. counties) upon early sown winter wheat. A maggot is hatched from the egg and feeds within the couch or winter wheat during the winter, ultimately giving rise to flies late in the following spring, when the barley is again attacked.

From what has just been said it is evident that the sooner the barley ear escapes from the surrounding leaves the less will be the risk of damage from gout fly, since the maggot cannot live upon the exposed ear. Naturally, early sowing contributes to early "earing," but as the date of sowing cannot often be much altered, certain experiments made at Rothamsted Experimental Station are of great importance, since it was discovered that the date at which the ear is produced varies considerably in accordance with the manuring employed. Nitrogenous manures, such as sulphate of ammonia, when used in excess, tend to retard earing, while phosphatic manures, such as superphosphate,

enable the ears to emerge sooner, with consequent reduction in gout-fly attack. Farmyard manure also contributes to early earing, and the deduction as a whole to be drawn from the trials is that the manure for barley (taking into consideration the residual manure left over from the previous crop) must be properly balanced as regards its main constituents, with perhaps phosphorus in slight excess, though in this latter case it is understood that the quality of the grain may be reduced slightly.

There remain the two other fairly important corn pests to be dealt with—*Corn Aphides* and *Corn Thrips*—and it is unsatisfactory that no remedy for either is known. Corn thrips are minute black insects (yellow when young) which may often be found between the husk of the wheat or oats and the kernel, and the result of their attack is "blindness"—*i.e.* empty husks with merely the shrivelled remains of a kernel. Corn aphides, or green fly, are found upon the ears of wheat, oats, etc., sucking the sap, with the result that poor, undersized grain is produced, mostly of tail quality. Both aphides and thrips may in some years cause a

very considerable reduction both in yield and quality of corn crops, but other factors may produce the same effect—*e.g.* weather factors may prevent the fertilization of wheat and oats, with the result that blindness occurs; it is seldom possible at harvest to be quite sure what has caused the failure. It is undoubted, however, that insects contribute very largely. No remedy, either by way of prevention or cure, is known for either of these pests.

CHAPTER X

POTATOES

POTATOES are more liable to diseases of a fungoid and allied nature than any other crop. They are a valuable crop in many systems of farming, and with moderate care most of the troubles that afflict them can be avoided. Potatoes grow well on a great variety of soils, but they crop most heavily in the fen lands or on loams of good quality.

Wart Disease.—At one time wart disease, caused by *Synchytrium endobioticum*, seemed to threaten the very existence of potato-growing in this country. This disease transforms the eyes of the tubers, and sometimes entire tubers, into monstrous growths which look like pieces of dirty cauliflower. Upon disintegration of the growths the germs of the disease pass into the soil, where they persist for many years. During the early phases of investigation of this serious disease it was noticed that some varieties of potatoes grown in contaminated soil were never attacked by the disease, and it was subsequently found that these varieties were

immune from wart disease under all field conditions. This discovery of immune varieties is the foundation of the present control of the disease. All existing varieties of potatoes have been subjected to repeated tests by the Ministry of Agriculture in England at the National Institute of Agricultural Botany at Ormskirk, by the Board of Agriculture in Scotland and by the Ministry of Agriculture in Northern Ireland, to determine whether they are immune from or susceptible to wart disease. New varieties are similarly tested as they appear. By the terms of the Wart Disease Order made by the Ministry of Agriculture and Fisheries, under the Destructive Insects and Pests Acts, this disease is a notifiable one, and land which is contaminated by it may be planted only with varieties of potatoes immune from the disease. From certain "infected areas" only ware potatoes of immune varieties may be consigned to any part of England which is not an "infected area." At the same time potatoes grown for seed purposes are inspected by officials, and are certified to have been grown on land free from the disease, and, in the case

of immune varieties, to be true to varietal type. Although wart disease is more widespread in the country than before the war, the large potato-growing areas in the east of England are still practically free from it.

The following is a list of some of the more important varieties of potatoes which are immune from wart disease:—

Early—

Snowdrop
Immune Ashleaf
Edzell Blue

Second Early and Early Maincrop—

Great Scot	Abundance
Majestic	The Ally
Golden Wonder	Arran Consul

Late Maincrop—

Kerr's Pink

At present there are few satisfactory early varieties of potatoes which are immune from wart disease, but potato breeders are paying much attention to remedying this deficiency.

Warty tubers should be burnt. They should on no account be fed to pigs unless they have

been well boiled, as otherwise the spores are liable to be spread in the dung.

Powdery (Corky) Scab.—Although powdery or corky scab may be less widespread than wart disease, being often confined to small gardens in the north and west, it is occasionally found in farm crops, and causes considerable damage in a wet season. The parasite (*Spongospora subterranea*) causing this disease is not a true fungus, but is an organism, like that of finger-and-toe, half-animal and half-plant in character, which causes infection by way of the soil. Tubers affected by this disease show very diverse symptoms, which may range from small scabby spots, powdery or corky in appearance, to considerable outgrowths and deep cankers extending over more than half the tuber. The germs of this disease may remain alive in the soil for a number of years, so that potatoes should not be grown again in heavily contaminated soil for a considerable period. No other crop is attacked by this parasite. Anything that can be done to improve the drainage of infected land will be advantageous, as this parasite is serious only where the water-content

of the soil is high. Additions of lime to infested soil merely aggravate the disease. There are no varieties of potatoes which are immune from this disease, so that it cannot be avoided as can wart disease. Powdery or corky scab may be transmitted by the tubers, so that care should be taken to exclude from use as seed any tubers affected by this disease.

Common Scab.—This is a purely superficial disease of the tubers, but it sometimes occurs intensively in field crops. The scabs are usually scattered irregularly over the surface of the tubers, but being only skin-deep are of no economic importance, unless they are so numerous as to render the tubers unsightly, thereby causing a reduction in value. Occasionally common scab is so bad as to destroy the "eyes" of the tubers. This blemish on the tubers is caused by a soil-inhabiting organism, but on land subject to rotation is only rarely of consequence. Excessive liming of the soil facilitates the development of this form of scab; on the other hand, any form of green-manuring of the land carrying potatoes tends to reduce it to negligible proportions.

Blight.—Potato blight is a fungus disease, caused by *Phytophthora infestans*, which varies greatly in severity from season to season according to weather conditions. In a wet summer great havoc is often caused by it in the south and west, and in 1845-1846 the famine in Ireland was largely attributable to it. The blight fungus first affects the haulm, causing black spots thereon; and spores falling on to the soil from the leaves bring about infection of the tubers. In wet weather with a fairly high temperature a blight epidemic may spread so rapidly as to cause a more or less complete blackening of the haulm over whole fields in the course of a day or two. Blighted tubers show a brownish discoloration under the skin, which may extend deep into the flesh, and in a very wet season such tubers frequently become completely rotten in the ground or in store in consequence of secondary attack by other organisms.

The time of appearance of the blight fungus in an epidemic condition varies considerably in different parts of the country, it being usually earlier in the west and south than in the east

and north. Although in the west it may appear epidemically in July, or even earlier, it is generally little in evidence in the eastern counties until August. Early varieties of potatoes are nearly always lifted before the blight fungus is apparent, and thereby escape attack. Second early varieties are also sometimes lifted before blight becomes serious.

For protection of maincrop potatoes against a severe attack of blight it is now well known that if the haulm be sprayed with a copper fungicide, such as Bordeaux or Burgundy mixture, shortly *before* the blight appears, and again later, the crop is protected against any considerable loss from this disease. Foliage which is properly covered with Bordeaux mixture cannot be effectively attacked by the blight, and hence the tubers also remain free from infection. In addition, the protection afforded by the fungicide allows of a longer period of growth in the haulm, with the result that the yield is increased. Potatoes badly affected by aphides, and crops in the vicinity of smoky towns, should not be sprayed, as the haulm may be badly scorched by the fungicide under these conditions.

There are several proprietary copper fungicides on sale nowadays, but for anyone who wishes to make up his own mixture the following particulars are given, the home-made preparation being the most adhesive to the foliage and the most efficient fungicidally:—

Bordeaux Mixture.—Dissolve overnight 4 lb. of copper sulphate (bluestone)[1] in 35 gallons of water in a barrel. Slake gradually 4 lb. of stone ("fat") lime and make up the milk of lime to 5 gallons. Strain the milk of lime through a sieve into the solution of copper sulphate, and then stir, when a flocculent blue precipitate will be formed. Transfer to the spraying machine, which should be made of or lined with copper, and which should be provided with nozzles throwing a fine, mist-like spray. For potatoes grown as a farm crop a horse-drawn spraying machine is necessary, capable of spraying several rows of potatoes at a time. 100 to 120 gal. per acre should be applied. The spraying should be done in fine weather and should be timed to take place just before blight is liable to appear in the district, though the farmer must be guided to some extent by the season. A second spraying should be given a fortnight or three weeks after the first application, and sometimes a third spraying is desirable.

Burgundy Mixture.—Use 5 lb. of washing soda instead of 4 lb. of lime, otherwise make up as for Bordeaux mixture.

Where there is difficulty about the water supply a powder may be used instead of a wet

[1] Copper sulphate should be guaranteed 98 per cent. pure.

spray, but it is essential that the powder should be applied while the dew is still on the haulm, otherwise it will not adhere well.

Where potato blight is prevalent a sprayed crop will yield from 1 to 2 tons more sound ware than an unsprayed crop—an increase which covers the cost of spraying several times over. However, in a dry season, the blight fungus may be very little in evidence and the spraying may have been done in vain, so the farmer must decide for himself whether in his district it pays over a period of years to spray the potato crop or not. In the south and west, where the summer rainfall is heaviest, potato blight is so prevalent that it undoubtedly pays to spray regularly. In other parts of the country, with the possible exception of the Fens, it has not yet been proved that potato-spraying is a paying proposition. Further experimentation in this respect is desirable.

Other measures that can be taken to reduce the incidence of blight are deep earthing up of the potatoes, which tends to reduce tuber infection, and the lifting of the crop (if possible in dry weather) when there is no danger of

multitudes of blight spores being present in the air. If, for instance, maincrop varieties are lifted somewhat earlier than usual to avoid tuber infection, this should not be done when the disease is in an active state on the haulm, as the spores are liable to alight on the tubers while lying on the ground, thereby leading to considerable loss from blight in the clamps. At the time of storage, care should be taken to eliminate blighted tubers.

Most varieties of potatoes are susceptible to blight, although "President" (including "Scottish Farmer" and "Iron Duke") and "Evergood" are less susceptible than others. A comparatively new variety, "Arran Consul," has so far been extremely resistant to blight. "Majestic" also is tolerably resistant.

"Degeneration" Diseases.—It has long been known that if home-saved seed potatoes are used year after year in many parts of England, particularly the south, the crop rapidly becomes poorer until it is commercially worthless. This degeneration is marked by a progressive dwarfing of the haulm and the production of an unusually large proportion of small tubers. It

is now realized that most of this degeneration is produced by infectious diseases of a curious type, in which it is suggested that the parasites are so small as to be invisible under the highest powers of the microscope. These diseases are of the "virus" type and are perhaps similar in character to such well-known troubles as foot-and-mouth disease and swine fever in animals. The "virus" diseases of potatoes—of which there are several—are carried from plant to plant by minute insects, chiefly green fly and perhaps also the little "leaf hoppers" which are often common in potato fields and are responsible for the small white spots on potato leaves. Insects transmit these degeneration diseases in much the same way as malarial fever (caused by a minute animal parasite) is carried from man to man by mosquitoes. The insect-carried "virus" disease does not cause much commercial loss until the season after its introduction into a plant —*i.e.* a potato plant sucked by the aphis and thus infected by the disease in the summer of one year would show little signs of damage, but the "seed" from that plant would probably be a total or partial failure the next year.

The disease known as "leaf roll" is probably the most serious cause of degeneration in potatoes in this country. In the early stages of attack the upper leaves show a rolling upwards of their margins; if seed be saved from such plants the rolling becomes more pronounced in the next generation, and is accompanied by dwarfing of the whole plant and reduction in size of the tubers. If such a diseased stock be grown on for another year the symptoms are even more intense and the crop may be practically worthless.

"Mosaic" is another of these virus diseases, and is characterized by a yellowish mottling of the leaves in the early stages of attack. Although this disease does not cripple the plant so seriously as does "leaf roll," except when pronounced dwarfing and crinkling of the haulm is present, it is nevertheless responsible for serious loss of yield. There are other somewhat similar troubles, and plants are not infrequently affected simultaneously by more than one of these degeneration diseases. Formerly many of these diseases were grouped together and in some parts of the country were often collectively spoken of locally as "rust"

or "curl" in consequence of the browning and shrivelling of the leaves in the later stages of attack.

Long before the nature of potato degeneration had been discovered, it was known that the continued introduction of seed from Scotland or Ireland every year or every other year enabled heavy crops to be grown in England, and this has become the regular practice with the best potato growers. "Seed" saved at home from a sound field usually gives a good crop in the following year, but in England it is unwise to save seed for more than one year. Potatoes from some parts of Scotland are comparatively free from virus diseases, especially those grown in the north, and great care is taken by the best Scottish growers to rogue out plants showing signs of infection, so that the tubers shall not be kept for seed purposes.

Large potato growers in the southern part of England should obtain seed grown in the more northerly parts of Scotland if possible, or should ask for a guarantee that the plants from which the seed was taken were free from degeneration diseases. In the south of England good

results are often obtained with "once-grown" Lincolnshire seed. It would be worth while for large growers in the south either to inspect the growing crops from which seed was to be purchased, or, alternatively, to grow their own seed in the north of Scotland. Potato growers in Bermuda, who supply the early potato market in New York, have recently been confronted by the same problem of keeping their crops free from degeneration diseases. This has been successfully accomplished by inspecting the growing crops of potatoes in Nova Scotia and Long Island, whence the seed is obtained, and making sure that these are free from virus diseases.

The following maincrop varieties in this country are usually more resistant than others to these infectious degeneration diseases: The Ally, Great Scot and Arran Consul; but even these cannot be guaranteed against deterioration in the southern parts of the country.

Eelworm Diseases.—Two kinds of eelworms have been detected upon potatoes. The first is apparently the same species which causes such harm to sugar-beet on the Continent,

and which is already known to attack many crops in Britain. As in the case of most eelworms, however, races may develop with a taste chiefly for a certain crop or crops, and these potato eelworms probably take no interest in beet! However this may be, it is clear that wherever potatoes are grown frequently on the same land, there is likely to be a great increase in these eelworms, which are gravely suspected of causing serious injury to early potatoes, though at present maincrops, even when heavily infested, seem to show no symptoms of suffering a reduction in yield. Eelworms are of course exceedingly small, and are usually invisible to the naked eye, but the beet eelworm females can be seen when they are leaving the potato roots, which they do when the plant is beginning to ripen off. These female eelworms then look like minute white or brown pear-shaped bodies, about a quarter the size of a pin head, and they will be found upon the smaller roots and root fibres, not upon the tubers or main stems.

The beet eelworm, however, is not the only eelworm which has developed a taste for potatoes, as recently the stem eelworm—which

causes Tulip Root of oats, "bloaty" onions, and eelworm disease of narcissus and clover—has also been found upon potatoes, but so far not commonly, causing a rot of the tubers sometimes mistaken for that due to "blight" (common potato disease).

At the moment of writing, the attacks of both species of eelworm upon potatoes have been so recently discovered and so little investigated that no further information can be given, except to suggest that they seem to be correlated with frequent growing of potatoes on the same land. If, for instance, potatoes are thus grown for many years in succession, eelworms will probably be found in abundance, and in proportion to the frequency with which the potato crop occurs in the rotation. The taking of the potato crop once every three years—as is not uncommon in the Fens—is probably running very close to the danger-mark as far as eelworms are concerned.

Other Insect and Animal Pests.—Potato tubers may be badly damaged by *Wireworms*, which have been already dealt with in Chapter VIII.; it need only be added that although the

potato crop may suffer, the soil is thus sometimes freed from the pests owing to the fact that many are removed in the tubers from the field. A farmer in the north of England once told one of the writers that although he had had to feed the whole of a crop to pigs on account of the wireworms in the potatoes, he was not sorry, as a badly infested field was rendered relatively free from the pests, which were afterwards not sufficiently numerous to cause any damage. This experience is not universal, as wireworms have usually left the potatoes before lifting time, but it does sometimes occur.

Slugs may prove excessively injurious in damp soil, especially the type of soil found in industrial districts which has been heavily dressed with town refuse. Nothing can be done to help the attacked potato crop, but in the intervals between the potato crops, dressings of lime, good cultivation and the replacement of town refuse by artificial manure should be effective if the land is not too moist.

As regards the potato leaves and haulm, insect pests are not very harmful. *Aphides* (green fly), which are of serious importance

as regards the transmission of "degeneration diseases," only occasionally cause a direct reduction of crop. If it were worth while, a nicotine dust, or even the addition of nicotine to the spray mixture used for blight, should prove an effective control, but this has not been tried in Britain. It is worth remembering, however, that an aphis-attacked crop seems specially liable to be injured by the copper fungicides used against blight. Of other insects found on the leaves, *Capsid bugs* (not the kind found upon apples) are sometimes injurious in small fields and along headlands, but they are hardly of importance to the average potato grower. The same may be said of a *Flea Beetle*, which migrates from nightshade to potatoes, and eats holes in the leaves; and of the caterpillar of the *Rosy Rustic Moth*, which burrows in the haulm, causing its death. It is fortunate that England is at present free from such serious potato pests as the *Colorado Beetle* and the *Potato Moth*, which cause great injury in certain countries abroad. As it is only too probable that such pests as these will sooner or later attempt to gain a foothold, it is very important that potato growers

should seek entomological advice as soon as any strange pest is observed in their crops, for only by early action is there any hope of stamping out a foreign pest. The establishment of the Colorado beetle, for instance, would result in potato growers being forced to spray at least twice a year, and perhaps more often, in order to secure a full crop, so the matter is by no means trivial.

Storage Diseases.—Great care should be taken in the storage of potatoes, because no crop is more liable to wastage in the clamp, and because it often pays best to keep potatoes until towards the end of the winter. Reference has already been made to the danger of blight developing in the clamps if the tubers are lifted when the disease is in an active state on the haulm.

A soft rot of the tubers caused by a bacterium (*Bacillus atrosepticus*) is also sometimes destructive in the clamps. This organism occasionally attacks the growing plant and causes a soft black rot of the stem at soil-level, this stage of the disease being known as *black leg*. If tubers slightly affected by this bacterium are included in the clamp the rot may spread rapidly.

Perhaps faulty construction of the clamps or pits is most often responsible for rotting. The clamp should be made in dry weather. It must allow of sufficient protection from frost and at the same time afford adequate ventilation, which is best provided by outlets stuffed with straw situated at intervals along the clamp. Potatoes breathe, like all other living tissues, and if ventilation is defective the tubers become literally suffocated, and the condition known as "going black" intervenes, producing a black discoloration of the tubers. In a badly ventilated clamp bacterial putrefaction, accompanied by the evolution of considerable heat, may also proceed at an alarming rate, causing a soft rot of the tubers.

Care of Seed Tubers.—Wherever possible, seed potatoes should be sprouted in shallow boxes in the light a month or two before planting. This has the effect of producing vigorous young shoots, and provides an additional opportunity of discarding any tubers which are not up to the requisite standard of health. If, for instance, disease be latent in or near the eyes of the tubers, the shoots will not develop properly, and such tubers can be eliminated at planting

time. Otherwise they would have been planted, with the result that blanks in the rows would occur, or, alternatively, greatly weakened plants. Diseased tubers often sprout prematurely. Careful trial has shown that with well-sprouted seed the yield is increased by at least a ton an acre. Under no circumstances should seed tubers be planted that have developed long spindly shoots in the clamps. Where the more expensive newer varieties of potatoes are being grown it is often advisable on grounds of economy to cut the seed tubers into two or more pieces, but this should be done only immediately before planting, so that the exposed surfaces do not become desiccated.

CHAPTER XI

ROOTS

(*Turnips, Swedes, Mangolds*)

Insect Pests.—The root crop is one which is in danger from insect pests from the moment the seed germinates practically until it is harvested; at the same time it usually manages to pull through, although re-seeding two or three times may be necessary on account of attacks by the "flea" or "fly"—really a small jumping beetle. There are several kinds of turnip *Flea Beetle*, mostly black with a yellow stripe down each wing-case, and one kind, bronzy green, which chiefly concentrates upon mangolds. Both the turnip and mangold fleas, as of course the reader knows well enough, attack the seed-leaves of the crop as soon as they are through the ground, and even before they are clear of the soil. Later, in very unfavourable seasons, when the growth of the plants is almost stationary, they may attack the crop in the "rough leaf," gnawing innumerable little holes in the leaves; this form of damage more often occurs in gardens, and the injury to the seed-

leaves is the really serious matter on the farm. From the practical point of view, flea-beetle attack is essentially a matter of weather, for under moist, growing conditions the crop, whether turnip or mangold, produces leaves faster than the beetles can eat them. Under the opposite conditions, drought and hot sun (which in spring are often combined with cold, frosty nights) render germination both slow and irregular, so that the beetles are concentrated upon few plants, which themselves can make little growth, and in consequence the entire crop is eaten off as it appears. In some cases, particularly if the tilth is not too good, the young seedlings are eaten off even before they have grown clear of the soil, so that the rows cannot be distinguished except by the closest examination, and it is then sometimes thought that the seed was bad and had never germinated.

In regard to practical measures of dealing with the pest, the ordinary "treatment" is to wait for favourable weather conditions, and, if they are not secured, to re-seed the field until a plant is obtained. This method of tackling the problem may seem primitive, but if the

cost of re-seeding be calculated, it will be seen that there is not much money per acre to spend on better methods, which clearly must be both cheaper and more certain if they are to compete with re-seeding. There are, however, certain measures which have a limited popularity. In the first place the seed before sowing may be soaked in turpentine or paraffin, with the idea of protecting the plant in its earliest stages. Since little, if any, of the liquid is absorbed by the seed coat, it is difficult to see how this remedy can work (under experimental conditions one of the writers has so far had no success), but the method has sufficient supporters to warrant the supposition that it must at times give fair results. It seems possible that enough paraffin or turpentine is introduced into the soil with the seed to disguise temporarily the smell of the germinating seeds, which presumably attracts the beetles to the fields. As soon as the crop has actually germinated, and the rows can be seen, there are several so-called remedies. The oldest and most simple is hoeing, which is so well known from the old folksong. Dusting the plants with lime or soot is a variation

of the same idea, which aims at coating the young plant with fine dust, which the beetles do not like. The lime or soot is probably more efficient than soil in this respect, but hoeing has the considerable advantage of conserving the moisture in the soil. A nearer approach to a modern treatment consists in spraying the seedlings with an insecticide, such as paraffin emulsion, which keeps the beetles away until the plants can withstand their attacks. The late Mr Elwes of Colesbourne used to say that he could always protect his turnips in this manner, adding that it was the only help in farming he had ever got from entomology!

One of us has tried spraying with nicotine in the case of certain specially valuable crops (grown for seed), but any spraying, or dusting with dry powder insecticide, has the disadvantage that it cannot be applied (or perhaps is not usually applied) before the rows can be seen, whereas the worst attacks and most serious damage take place before this. It would be sounder in principle, though probably too costly, to spray the whole field a week or two after sowing, using some deterrent substance,

in an attempt to nullify for a time the scent of the seedling plants. On a small plot—as, for instance, cattle cabbage for transplanting—flea beetles can quite well be kept away by means of insecticides, naphthalene sprinkled over it at the rate of about 2 lb. per sq. rod being sufficient.

One other method of attacking the flea beetle remains to be mentioned; this consists in using a "beetle catcher" of some form. All such catchers depend upon the fact that the flea beetles when disturbed jump into the air, and they can therefore be made either to jump against, or to fall upon, some sticky surface from which they cannot escape. The most simple form consists of a metal axle six or seven feet in length, two wheels, such as old cycle wheels, and a pair of long handles—six feet long or more. To the axle are attached bags or cloths long enough to trail on the ground two or three feet behind the axle when the machine is pushed along. The bags are covered with tar on their under sides, and the whole contraption is pushed up and down the field. As the sacks sweep along, the beetles jump forwards and upwards in an

effort to escape, and stick to the tar. There are many improvements upon this simple form of machine, mostly of a kind to prevent the tarred surface from getting quickly covered with dust and soil, which soon renders it useless. Beetle catchers of this sort can work fairly well, but they seldom do, and therefore find little favour as a whole. One difficulty—perhaps *the* difficulty—in their use is that the man or boy pushing the machine will not take the trouble to keep the sticky surface freshly tarred and sufficiently sticky, or, indeed, put any real effort into the matter. To the average labourer (and to many other people as well) beetle catching is anyhow a silly business, fit only for those who are weak-minded, and when it involves pushing an absurd piece of apparatus about, it becomes something worse, as it renders the pusher open to all sorts of pleasantries from other farm hands more fortunately occupied.

After the root crop has passed the stage in which it is liable to destruction by the flea beetle, it has to run the risk of damage from three other major pests, to say nothing of soil insects and a host of minor pests to which space

prevents any reference. These three pests are *Cutworms*, *Diamond Back Moth*, and *Aphides* (green fly), which are all invariably present, but which only appear in sufficient numbers to cause serious loss at very irregular intervals. Reference has already been made to cutworms in the chapter upon soil insects.

The *Diamond Back Moth*, or rather its minute green caterpillar, feeds upon the leaves of turnips and many allied plants (not mangolds), living in a silk web on the under sides of the leaves. The caterpillars do not eat right through the leaf but leave untouched the upper skin, with the result that the leaves shrivel up and become whitish and then brown, the crop of course ceasing to make further growth. As a rule the serious attack occurs at the end of July, but it may continue through August and September. The epidemics of this insect are so irregular that they give no opportunity for the working out of any definite plan of campaign, and when an outbreak occurs, measures have to be extemporized in any way which may be possible upon the farm. The simplest measure is perhaps to "brush" the crop—as, for instance,

by attaching gorse or other brushwood behind a horse hoe in such a way that the turnip leaves are brushed over, the twigs dragging across the under sides of the leaves and so injuring the caterpillars and tearing them out of their webs. Where the necessary apparatus is available, spraying, and especially powder spraying, should be far more effective. A nicotine or derris (tuba root) dust applied with a potato duster should do what is required, provided it can be so adapted as to get the powder well under the leaves. Whatever treatment is attempted, the important thing is to begin sufficiently soon, before the crop is ruined. Stress is laid upon this point, because in the last serious outbreak (1914) the millions of little caterpillars at work in the fields were not noticed until the leaves of the turnips were destroyed, when the best of measures could not have done any good. Weather is an important factor in regard to this pest, and a week of heavy rain reduces a bad outbreak to negligible proportions.

The third pest, *Green Fly*, usually occurs somewhat later than the diamond back moth, say, in

August and September, and perhaps October. The most abundant species on turnips is a very common green aphis or green fly, which also feeds upon potatoes and many other plants. On mangolds, the chief species is the black bean aphis, but a green species is not uncommon. These pests are mentioned because they can be very destructive, but no means of controlling them seems yet to be known. Dust sprays ought to be effective if the apparatus be available and the cost of a nicotine dust be not too great.

Fungus Diseases.—Mangolds are particularly free from fungus pests. A rust fungus (*Uromyces betae*) not uncommonly occurs upon the leaves, producing brown spots chiefly on the under side, but it reduces the yield appreciably only when the crop is grown on land which has received excessive quantities of nitrogenous manure. Mangolds and sugar-beet are occasionally attacked by a downy mildew (*Peronospora Schachtii*), which may severely harm the foliage. Further reference to this disease is made in the concluding chapter (p. 183). The same care should be taken in the clamping

of mangolds as in the storage of potatoes; where there is protection against frost and adequate ventilation no appreciable loss should be found when the clamps are opened. The conditions under which rotting of mangolds in the clamp occasionally occurs are not yet clearly understood, but this is sometimes due to fungus attack following slight frost injury.

With turnips and swedes the most serious parasitic disease is *Finger-and-toe*, *club root* or *anbury*, which is most prevalent on lands deficient in lime, especially in the north during a wet season. This disease causes abnormal swellings on the roots, which frequently rot away in consequence of secondary invasion by other destructive organisms from the soil. The germs of this disease persist in the soil for a number of years, and one of the ways of reducing losses from it is to extend the rotation, as in parts of Scotland where temporary grass leys are retained longer than usual. Sourness of the land, which is a necessary condition predisposing to the disease, can be corrected by the addition of a heavy dressing of freshly slaked lime, up to 4 tons per acre being some-

times required, although the cost of such a heavy dressing is sometimes prohibitive. The lime should be applied to the land before sowing the crop which precedes turnips in the rotation. On land liable to finger-and-toe disease, basic slag or bone meal, rather than superphosphate, should be the phosphatic manure for the turnip crop, as superphosphate tends to increase sourness. Anything that can be done to facilitate drainage will assist in keeping down the disease. Fast-growing varieties of swedes and turnips are less liable to finger-and-toe than slow-growing kinds, probably because they pass through the critical young stages of growth too rapidly to allow of infection taking place to a serious extent. Some varieties of swedes and turnips are less susceptible than others, notably some Danish varieties of the former (*e.g.* Studsgaard Bangholm), but more information is required about this. In some parts of the country swedes are less attacked by the disease than are turnips. It is extremely dangerous to feed diseased roots to stock, as thereby the spores are spread with the manure.

Several common weeds—*e.g.* charlock—are

also liable to finger-and-toe, so that every effort should be made to keep the land clean. Other kinds of Brassicae, such as kale, may be attacked by this disease, but the damage to them is usually of a less serious nature than with turnips or swedes.[1]

After a dry summer the foliage of swedes is often seen to be covered with a white mildew (*Erysiphe polygoni*), but this fungus causes only trifling damage to the crop.

[1] Other gall-like swellings on the roots of turnips, swedes and other Brassicae are often due to the turnip gall weevil, but such galls may be recognized by the fact that they contain a white grub. The turnip gall weevil is a common pest, and renders the roots unsightly, but it does not usually cause an appreciable reduction in the yield. It need not therefore be discussed at length here.

CHAPTER XII

FORAGE AND PASTURE CROPS

"Clover Sickness."—If clover be grown too frequently on the same land it is very liable to disease, which is usually spoken of as "clover sickness," in consequence of the opinion that the disease persists in the soil for a number of years. In point of fact there are two distinct diseases that in the past have been referred to as "clover sickness"—one caused by an eelworm (*Tylenchus dipsaci*), to which the term "sickness" alone should be applied, and the other caused by a fungus (*Sclerotinia trifoliorum*), which is better called "clover-rot."

Eelworm Disease.—The eelworm that causes one of the most serious diseases of clover is a race of the common stem eelworm, which also attacks oats and many other plants. The signs of damage usually appear in the autumn, when it is noticed that patches in the field fail to grow, and contain plants which are paler in colour than the rest of the field. Under a detailed examination such plants are seen to have their shoots swollen and stunted, with a tendency for

the older leaves to die off and the production of new but abnormal foliage. At this stage the plants are full of eelworms, which, however, cannot be seen with the naked eye. As the attack progresses the leaves die away from the diseased plant, and the crown also rots and dies. The patches in the field usually spread outward during the autumn and winter, and result in the loss of the crop or of the part of the field most affected. As regards treatment there is no cure, though there may be some natural recovery, which, however, is less likely than in the case of the fungus disease.

From the practical standpoint it is necessary to starve the worm out by not growing crops liable to attack for a period of from six to eight years; it is therefore very important to know exactly what plants other than red clover are susceptible to the clover race of the pest. In the first place, there is no evidence to show that the oat race of the stem eelworm can pass to clover, but a good deal of evidence to the contrary. The same applies to the races of stem eelworm found upon other crops not related to clover, and the practical problem therefore is to find

what crops can replace red clover in the ordinary rotation. Amos (*Jour. Roy. Agric. Soc.*, 1918), as a result of growing the crops on heavily infested soil, states that annual red clover, perennial red clover and alsike all suffer severely, crimson clover slightly, white clover and trefoil rarely, with sainfoin, peas, beans and vetches showing no disease. Lucerne was doubtfully affected. Since some of the crops just stated to be but slightly attacked have suffered under other conditions, the above list may have to be somewhat modified; but in any case there is clearly a choice of crops which can be used to replace the clover break without upsetting the rotation. On soil where it succeeds, sainfoin is perhaps the best substitute.

Clover Rot affects chiefly the common red clover, but crimson and alsike clover are liable to attack, and, to a lesser extent, trefoil and sainfoin. The disease usually first becomes evident in late October or November, particularly if the weather is wet and warm. The rot breaks out at a number of centres in the field, from which it spreads, causing a blackening of the plants as it proceeds. If cold or dry

weather intervenes, the progress of the disease may cease, although it may resume its development later in the winter or in the spring. In severe attacks whole fields may be lost, but generally only a partial loss results. Partly in consequence of this disease it is customary to grow clover on the same land only once in eight years, and this extension of the rotation probably has the effect of reducing the intensity of attack.

Clover rot is often most severe when the growth of the plant is luxuriant during the first winter, the dense foliage facilitating the spread of the fungus from plant to plant. Recent experiments by Amos indicate that where the clover is grazed by sheep during the first autumn or winter the disease may be considerably reduced in consequence of the eating off of much of the foliage and the consolidation of the ground, for in this way the growth of the fungus is materially checked. If the clover is kept for a second year the disease is never so severe as in the first season. There is no doubt that infection by this disease occurs in the main from wind-borne spores arising from the black fungus bodies (sclerotia) formed in plants in the old clover leys

that have been killed by the disease during the previous season; some of these sclerotia may have passed into the soil on the disintegration of the dead plants. It is therefore advisable, wherever possible, to plough in deeply the remains of the old clover early in October in order to bury the black fungus bodies (sclerotia) which give rise to spores when near the surface of the ground. Where clover rot is rife, and the land is suitable, it is well to replace the clover, wholly or in part, by sainfoin or similar fodder crop that is less susceptible to the disease. Italian rye-grass, which is often sown with clover, is not attacked by this disease.

In regard to both the eelworm and the fungus disease there is a mystery which is not yet solved concerning the conditions under which clover becomes subject to the pests. Amos quotes a case where no clover had been grown on the field for twenty-two years, but, when sown, failed entirely from eelworm attack. On the other hand, clover will persist for years in a pasture and never show signs of attack; there is also the often-quoted case of clover springing up and remaining healthy along the paths through fields so "sick" that

they would grow no clover at all. It has therefore been suggested that some other factor enters into the occurrence of these two clover diseases, and that, grown under right conditions, the crops would resist attack. There is no evidence to show what these conditions are, or even if they really exist, but the point of view is worth bearing in mind.

Weevils.—Apart from the above-mentioned diseases, which are the most serious, the clover crop has several minor enemies, and at least one which at times causes very great losses. This "one," for the term is used collectively, comprises one or more species of minute weevils, the clover seed weevils, which are capable of completely ruining a seed crop. These little beetles winter as adults in stack bottoms, rubbish, etc., and in early summer lay eggs in the flowers of the first cut. The larvæ resulting from these eggs feed within the flower head, doing no obvious damage to a crop for hay, and in due course give rise to a second brood of beetles, which usually hatch out of the stacks in July. The beetles of this second brood lay eggs in their turn in the developing heads of the second cut, and if the

latter is reserved for seed, the larvæ may cause such destruction as to leave practically no seed at all. There is as yet no remedy, but the lines along which it may be sought are in timing the first cut so as to render it unfit for the larvæ of the first brood. This would involve cutting it at the earliest possible date, and might not be effective, but it is worth trying.

Crown Wart of Lucerne.—In the drier parts of the country, lucerne is a particularly valuable fodder crop. Lucerne is very robust and is liable to only one serious fungus pest, crown wart, caused by *Urophlyctis alfalfae*, which is still, however, comparatively rare in this country. This disease causes abnormal swellings around the crown of the plant, preventing to a great extent the formation of new shoots after cutting. Affected plants often flag on a hot day. The effect of the disease is to shorten the time the lucerne ley can be kept profitably for fodder. Crown wart is most common after a cold wet spring on land where surface water collects. The germs of the disease remain alive in the soil for several years, and hence lucerne should not be grown again in infected land for a considerable period.

Forage and pasture grasses are extremely free from serious fungus pests. They are sometimes affected by the ergot fungus (*Claviceps purpurea*), which replaces the seed by a hard black body that contains poisonous principles. It is important that ergoted grasses—*e.g.* rye-grass—should not be fed to lambing ewes, as the ergot is liable to cause abortion (see also p. 101).

CHAPTER XIII

PULSE

Insect Pests.—Although the insect enemies of the pea or bean crop are not very numerous, they are certainly severe, and no one can have grown these crops for long without having suffered to some extent.

Weevils.—As soon as the crop begins to come through the ground the first leaves are notched all round the edges by weevils—especially the striped pea weevil—and then for the following month or so it is a race between the peas or beans and the weevil. So long as the leaves are merely eaten round their edges no serious damage is caused; but when any substantial loss of leaf takes place, the plants grow slowly, and more and more leaf is eaten until none is left, when the weevils bite away the young terminal shoot, causing such plants to be of little use in future. Beans as a rule grow away from the weevil, but peas, if they meet with a drought, may be practically ruined. Since climatic conditions so largely govern the incidence of attack, the chief steps which can

be taken to prevent loss are those which help the plant to resist unfavourable weather—*i.e.* a sufficiency of readily available manure in the soil, and a fine tilth which can be kept from setting into clods. The weevils themselves tend to shelter under clods, while the plants are to some extent protected by the dust of a fine tilth. Any form of dust powdered on to the plants helps in this manner, and in the past road-dust, soot and lime, and the waste dust from pepper grinding, have all been used for the purpose. Under modern conditions it should be profitable to substitute for these more or less inert dusts a powder insecticide such as nicotine powder, but experimental work on the subject has hardly advanced far enough to justify any large-scale operations, though a small trial is certainly worth while. In the few cases where peas are attacked when six or eight inches high, spraying with lead arsenate or Paris green is effective, but some "sticker" such as calcium caseinate must be added to the wash, as the pea leaf is very "slippery" and the insecticide will otherwise run off.

Aphides.—After the pea weevil menace has

passed the crop is reasonably secure until about the month of June, when, in the case of the bean, the far more serious pest, the *Black Aphis* (black fly, collier or dolphin), may be expected, appearing just on the top of the young shoots. These aphides have flown to the beans from various weeds, such as poppies and docks, or spindle bushes (on which last they have spent the winter). If the weather is hot and dry the pests increase, gradually covering the whole plant, which becomes dirty with honey-dew and weak from the sucking of its sap by innumerable aphides. The pods fail to swell and the whole crop may be a failure. A spell of rough rainy weather, or even a heavy thunder-storm, may, however, so reduce the aphides in numbers that no appreciable damage is done, so that the result of an aphis outbreak is always a matter of speculation. So far as preventing damage is concerned, earliness is the great safe-guard, and for this reason winter beans are much safer than spring beans. When an attack manifests itself, little can be done, but attention to one minor particular is at times worth while. Not infrequently, before the field has become

generally infested, a plant here and there, probably along one side or near the hedge, will be noticed with its tip black with fly. It is then not an expensive matter to send a boy with a basket to pinch off these first-attacked shoots. The work may not always be effective in preventing further infestation, but it sometimes is so, and, being so little trouble, is worth trying. After this, nothing is usually done to attempt to prevent further injury—whether something ought to be done is another matter! The bean aphis itself is readily killed by insecticides, wet and dry. In a thick bean crop wet spraying is perhaps hardly practicable, but the development of dry powders, such as nicotine dusts, would seem at all events to bring an insecticide treatment more within the bounds of possibility.

While on this point a brief reference to the equally serious aphis pest of the pea (the *Green Pea Aphis*) may be made. This insect in some years causes very heavy losses to growers of peas. American growers have found it both practicable and worth while to treat their peas with nicotine dusts applied by a special horse-

drawn dusting machine, rather after the fashion of powder sprayers for potatoes, except that it is found desirable to "hood" the nozzles either by means of metal hoods or by attaching cloths in such a way that they trail over the nozzles and plants, and so keep the dust down among the "haulm."

The Bean Beetle.—Finally, two other pulse pests must be mentioned. The first is the bean beetle, the insect which causes the very familiar holes in the beans themselves. This beetle, often wrongly called the bean weevil, has nothing whatever to do with the insect previously mentioned which notches the leaves. The bean beetles lay eggs on the very young pods (almost before the flower is off), and the beetle grubs develop within the bean seed, turning first to the chrysalis and then to the beetle stage within the seed. Bean beetles are not very serious pests, for the loss of weight caused to the crop is relatively slight, but they may be of more importance in regard to the seed beans. Such beans almost always grow, but they offer less food to the young developing plant, and—worse still—the holes

offer a very convenient place of entry for pests of all kinds, both soil insects and otherwise. It is, for instance, suggested that the bacterial "chocolate spot" of beans is introduced into the seed by the bean beetle. Obviously a badly infested sample is better avoided for seed purposes.

The Pea Moth.—The other pest to which final reference must be made is a pea insect—the pea moth—which is especially destructive where the crop is grown for marketing ripe and dry, either for human consumption or seed purposes. This moth, like the bean beetle, lays its eggs on the young pod, but the caterpillar which hatches from the egg, after it has burrowed into the pod, feeds upon the outside of the growing peas, rendering each pea attacked quite useless for any purpose. These caterpillars, when full grown, burrow out of the pod again and spin cocoons in which to spend the winter. They may do so in the dry haulm on the soil or in almost any rubbish, but it is not yet known what they most prefer. Of remedies for the attack, there are none yet known, but if we knew where the caterpillars

preferred to spin up for the winter, the number of moths the following season might at least be reduced in number.

Fungus Diseases.—Peas, beans and vetches are but little liable to fungus disease. Peas are sometimes affected by the white mildew (*Erysiphe polgoni*) if sown late, which may reduce the yield. Although early peas escape from this disease there is need of the production of later varieties which are resistant to it.

Beans are occasionally affected by stalk rot caused by the fungus *Sclerotinia sclerotiorum*, which, when severe, may kill large numbers of plants, black resting bodies of the fungus being found within them. Such plants should always be burnt, otherwise these resting bodies will pass into the soil, and, germinating there another year, may infect other crops. Beans are also sometimes affected by a bacterial disease of the foliage known as "chocolate spot" (*Bacillus lathyri*), because of the brown discoloration it produces; in very severe attacks the yield may be greatly reduced, but the damage is often trivial. Care should be taken to obtain seed only from sound crops, as the

disease may be transmitted by the seed. The same bacterium causes the disease known as "streak" in tomatoes, and where these are grown under glass the disease is effectively controlled by the addition of light dressings of potash to the soil.

CHAPTER XIV

THE FARM ORCHARD

It has been said, often with some reason, that farming and fruit-growing do not go well together—that where both are combined in one holding one or other will be found in a neglected condition. But that this is not necessarily true is proved by numerous cases, especially perhaps in Kent. It must nevertheless be admitted that there are a great many farm orchards which are in very poor condition, and the reason is at least in part due to the fact that nothing is ever done to check the ravages of pests. The trees are usually growing in grass, and the orchard is treated primarily as a paddock, with the fruit as a side line, which may prove very profitable in years when, by a stroke of luck, the trees happen to bear a crop in a season of fruit scarcity. That the farm orchard is worthy of more consideration than this will be admitted by anyone who has seen the returns which result from a little additional care in the control of pests. It is not suggested that under farm conditions the same routine of pest control

can be practised as is carried out by the fruit-grower, but there is a certain minimum of care which from the purely commercial standpoint is well worth while.

Old Orchards.—Let us consider first the case of the old orchard—not the cider orchard, which is "a law unto itself," but the orchard planted years ago with different varieties of fruit, often of varieties which the fruit-grower proper has already discarded for kinds better suited to present conditions. Often a tree here and there will be found in a half-dead condition, or with branches which have broken off and are dying. Both from the insect and the fungus point of view, dead, dying or even weakly trees or branches are a menace to the rest of the orchard, as they are exceedingly susceptible to the attacks of pests, which spread subsequently to healthy trees. An annual cutting out and burning of the dead and dying wood (which will be full of pests) ought at least to be possible; and if the wounds made by cutting out branches can be covered with thick paint, and the temptation of using the tree trunks as posts be resisted, so much the better.

Fungus Pests.—As regards fungus pests, silver-leaf disease of plum- and apple-trees caused by *Stereum purpureum* and canker of apple-trees due to *Nectria galligena* are perhaps the most important. Badly cankered branches should be cut out. Silver-leaf disease causes first a silvering of the foliage, and this is followed by death of the branches and often of the whole tree. It is particularly important to cut out wood which has been killed by this fungus, as the disease is very infectious if neglected. If such dead wood is required for fuel it should be stored under cover, otherwise it should be burnt forthwith. Wood piles should not be allowed to remain in the open in the vicinity of the orchard, as they become a prolific source of infection for insect and fungus pests.

Insect Pests.—Of insect pests, those likely to do most harm are aphides (green fly), which curl up and distort the leaves, and caterpillars, which devour the foliage; the control of either involves spraying. Some readers may exclaim that the trouble and expense of getting spraying tackle and using it render the whole thing not worth while. If this remains their view after

a talk with fruit-growing friends, then it can only be suggested that they should cut down the fruit-trees as soon as possible, and if necessary substitute other trees for shade, for then they will at least prevent their holdings from acting as centres for the distribution of pests to the neighbourhood, while, further, they will not assist in bringing down prices by flooding the market with scabby and maggoty fruit. The majority of the occupiers of farm orchards are, however, alive to the money-value of decent fruit, and will probably be prepared to attack insect pests to the extent of one application of a spray fluid per year.

Spraying.—It remains therefore to consider how to get the best results on one spraying per annum. Obviously the County Horticultural Superintendent can give better advice on this subject than can be offered in this book, but the following is the kind of treatment which has been practised with success.

The first year in which spraying is begun one of the new tar-oil washes should be applied in winter, or, failing this, a lime wash in spring, just before the blossom buds begin to

burst.[1] The covering of the twigs and branches is more important than spraying the trunk, although the latter need not be neglected. Either the tar-oil wash or the lime wash will clean off all lichen and moss, and will control aphides whether on apple or plum, while it may do something towards checking caterpillars. Both washes will cause the trees to produce an obviously healthier type of foliage, usually with leaves of a better colour and larger size. Why this should be is not properly known, though obviously it is likely to be due in part to the relief from pests which the tree obtains. After this treatment the orchard will remain fairly clean as regards moss, etc., for two or three years, and so the following year the aphis attack can be chanced and the spray be directed specially against caterpillars by the use of lead arsenate, which should be put on as soon as the trees have produced any foliage —apple-trees for instance should be sprayed during the ten days or fortnight before the

[1] Tar-oil washes are much more efficient than lime washes in controlling pests, but they may cause some temporary damage to grass under the trees.

blossom buds open. The leaves around the trusses of bloom will then be coated with poison, as will the blossom buds themselves, and the young caterpillars on taking their first meal will be poisoned. Even if this spraying be done properly there may be caterpillars left, but as a whole they should be well in hand. Subsequent treatment must then be dictated by events in accordance with the class of pest which seems to be gaining the upper hand, but it should not be necessary to spray against caterpillars more than once in about three years, so that the intervening years may be devoted to dealing with aphides or other pests. This one-spray treatment cannot be expected to give a complete control of anything, but it will, as a whole, keep the foliage of the trees in reasonably good condition so that a crop can be carried—which is not the case when the leaves have been destroyed by aphides and caterpillars. This destruction of the foliage is of far more importance than is generally realized, for not only does it result in loss of crop in the year in which the pests are at work, but it also cripples the tree for at least one year afterwards, and sometimes for two.

New Orchards.—So much for the old orchard: as regards making a new farm orchard, there is little to be added. The spraying may be on much the same lines, but the choice of varieties is important, and equally so their spacing and care in early life. As regards varieties, a lot of miscellaneous kinds (perhaps bought at a local auction of foreign stock), each susceptible to different pests, should be avoided. Good English stock of one or two kinds of commercial value, known to do well in the district, and possibly for cooking rather than dessert, is obviously to be preferred; the spacing between the trees should be ample, or even excessive, as anything like crowding will treble the danger from pests. Protection from rabbits and stock is of importance; for, apart from obvious damage, even trifling wounds are sufficient to allow the entry of pests which would otherwise be powerless.

Danger of Poisonous Sprays.—Finally, a note may be added as to one question which always worries the owners of grass orchards—how soon can stock be put in the orchard after a poisonous spray has been used? The need for safety would

suggest as long a period as is practicable—say, a month—but it is probable that this is quite unnecessarily long, for grass grows so quickly in spring, and showers wash the poison so soon into the ground, that generally stock will eat little poison, if any, even soon after the trees have been sprayed. If stock belonging to others is to be put in the orchard, then it is wise to exercise additional care, for if one of the animals should die it may prove difficult to discover the cause of death; the insecticide may in consequence be suspected, and an expensive lawsuit be the result. In any case tubs and barrels, etc., used for lead-arsenate wash must be kept away from all stock; even when well washed out they may still retain enough poison to cause death, and they should therefore never be used for any other purpose.

Perhaps the authors may be forgiven for choosing at this point to utter a general warning as to the use of poison, since farm hands are often so very casual in the matter—usually, it must be admitted, without harm resulting. Nevertheless, what is to be thought of one man who carried cyanide of potassium in his

pocket together with his pipe and "baccy," and of another who kept the same poison in the kitchen store cupboard in a sugar bag? In both cases it was little short of a miracle that only wasps were killed!

Bush Fruit.—Bush fruit should be grown under conditions of clean cultivation. Gooseberries and red currants are very hardy, and little liable to pests and diseases if planted on well-drained soil of average quality. Raspberries and strawberries also are comparatively healthy when grown on a small scale.

Black currants are more delicate, and in recent years have been much subject to a disease known as "reversion," which often follows attack by the mite which causes "big bud." The latter is sufficiently serious, as it makes the bushes infertile and cripples the growth, but "reversion" is even more detrimental, causing a great change in the character of the leaves and a big reduction in crop. "Reversion" in black currants is probably a disease of the "virus" type, transmitted from plant to plant by pests, of which perhaps the one causing "big bud" is the chief. Once a bush has reverted it should be destroyed. The most

obvious signs of "reversion" are the production of malformed leaves, with a margin less divided than in healthy leaves, and the formation of abnormal flowers which are devoid of the hairy "bloom" typical of healthy ones. In planting black currants the utmost care should be taken to obtain bushes from nurserymen who propagate only from sound stocks.

CHAPTER XV

SOME GENERAL CONSIDERATIONS WITH REFERENCE TO OTHER CROPS

THE most economic methods for the control of the chief insect and fungus pests of farm crops have been briefly outlined in the preceding pages, but in a book of this limited size it is impossible to deal fully with all the crops sometimes grown on a farm scale in this country. No hard-and-fast line can be drawn between agriculture and horticulture, and in certain parts of the country — *e.g.* the Fens — horticultural crops such as celery, carrots and onions are grown on broad acres. Although treatment for the control of the chief pests of such crops, and of others not hitherto dealt with, cannot be described fully for lack of space, it is proposed in the present chapter, which summarizes the chief methods of control of the pests and diseases of the more important crops, to give illustrations from other crops of the manner in which their diseases can be controlled along the same general lines.

The viewpoint adopted in this book is that

prevention and evasion of pests and diseases are preferable to attempts at curative treatment. It has been shown also that with some insect pests and with certain fungoid diseases curative treatment is either hopeless, from the nature of the attack, or is barred by considerations of expense.

Resistant Varieties. — With fungoid pests the introduction and use of varieties resistant to or immune from the more serious diseases is one of the most hopeful means for the control of the heavy losses which these organisms cause. The production of such resistant varieties, combined of course with other desirable qualities, has been begun only comparatively recently by plant breeders, and there is still a great deal to achieve in this connexion. Such a method of control is complicated by the varying intensity of attack by specific diseases in different parts of the country, so that the work of the plant breeder is often increased by the necessity of elaborating resistant varieties for different districts. Occasionally a single variety will do well over large areas, but with most crops the principle of "local adaptation" of varieties will be a main consideration.

With all the more important crops work is actively in progress to combat disease by the production of resistant varieties. With hops, for instance, much work is being done in Kent in an endeavour to produce commercial varieties that will be less susceptible to attacks by "hop mould" (*Sphaerotheca humuli*) than those at present grown.

Manuring and Cultivation.—Slight modifications in manurial treatment and in methods of cultivation sometimes suffice to enable crop plants to evade disease. Stimulation of growth at a critical time by light dressings of sulphate of ammonia or nitrate of soda may enable a crop to grow away from a pest attack, potash manures tend to confer a measure of resistance to many fungoid diseases, and phosphatic manures may cause a sufficient degree of earliness in ripening to enable a crop to escape late attacks of pests and diseases. In the cultivation of flax, shallow sowing of the seed renders the crop less liable than usual to one of the fungoid diseases (*Colletotrichum linicolum*) known under the name of "yellowing." The extension of the rotation to reduce such a disease as

"finger-and-toe" of turnips has already been referred to. In other parts of the world where flax is grown on a large scale the land becomes "sick" through the continued cultivation of this crop, owing to the prevalence of a fungus *Fusarium lini*, and if ever the cultivation of flax is taken up more extensively in this country, such a disease could probably be evaded by a lengthening of the rotation. This disease of flax, however, is unlikely to be serious under British conditions, as the fungus causing it flourishes only at higher soil temperatures than those obtaining in this country.

Clean Seed.—Illustrations have been given of the necessity of the use of clean seed if certain serious fungus diseases are to be avoided. With all crops such a precaution is imperative. The fungus (*Colletotrichum linicolum*) which causes the yellowing and death of young flax plants is transmitted in the seed coat, and although the fungus can be destroyed by treating the seed before sowing with a mixture of finely divided copper sulphate and dry sodium carbonate, it is preferable to ensure that seed be taken from crops, or parts of them, entirely free from this

disease. The most serious fungoid disease of celery, known as "leaf spot" or "blight" (*Septoria apii*), is carried from crop to crop chiefly by the seed.

In the past some serious diseases have been introduced into this country owing to contamination of the seed. Onion smut (*Urocystis cepulae*), fortunately, still rare in this country, was perhaps introduced in this way, although it is now the soil which is the source of infection. A special responsibility rests upon growers for seed purposes and upon seed merchants to sell only seeds of crop plants which have been grown and harvested free from disease.

New Crops.—Both in agriculture and in horticulture new crops are introduced from time to time, and these may bring new diseases with them. Sugar-beet, the most important addition to the list of agricultural crops for many years, has not been grown long enough in this country to show whether it will be seriously affected by pests and diseases. As regards fungi there is one serious disease of this crop on the Continent, a "downy" mildew caused by the fungus *Peronospora Schachtii*, against which growers

should be on their guard, and which has already appeared in this country. This fungus causes a curling and thickening of the leaves of the young beet, crippling its growth; the fungus may also grow in the crown of the beet or mangold, and the disease is sometimes carried over from season to season by the retention of such beets for seed purposes. If the disease appears in a crop grown for seed, the affected plants should be destroyed.

So far as animal pests are concerned, sugar-beet is so closely allied to mangolds and other beets that all the pests of the latter crops may be expected to attack it. Some, such as the mangold fly, have already shown their capabilities in this direction, and, judging from Continental experience, may loom large in the future if the popularity of the crop proves of more than short duration. Also judging by foreign experience, other troubles must be expected, not so much by the introduction of new organisms from abroad as by the transformation into serious pests of insects and animals now present in the country but relatively harmless. First in importance in Europe has been the *Beet*

Eelworm (*Heterodera schachtii*), which causes land to be beet "sick," and at one time threatened the existence of the Continental sugar-beet industry. Forms of this eelworm are distributed throughout Britain on potatoes, oats, peas, etc. (see pp. 84 and 133), and it is practically certain that a "beet" form will appear if sugar-beet is grown too frequently on the same land—as happened on the Continent owing to the high profit yielded by the crop. On contaminated land an interval of six or seven years between successive sugar-beet crops has proved necessary, but with clean land, such as that of Britain, it should be safe to reduce this interval to four years.

As regards other potential pests, one of the more serious in Central Europe (also of importance in America) is a small moth, the *Beet Web Worm Moth* (*Loxostega sticticalis*), of which the caterpillars eat the foliage. This insect is very local in Britain, where it feeds on the wild plant mugwort, especially in the Breck Sand districts of East Anglia; if it should transfer its attention to sugar-beet, spraying will be necessary, either with an arsenical or other

caterpillar poison. There are other similar potential pests which the entomologist will have to watch, though they are not as yet of concern to the beet-grower.

Finally, as regards pests not yet present in Britain: perhaps the chief is a "virus" causing a disease known as *Curly Top* in the Western United States and carried by an insect (a "leaf hopper"). Fortunately it is difficult to see how this pest could be brought to Europe, and Britain should therefore remain free from it, but, even without it, enough has been said to show that the pests of sugar-beet are sufficiently numerous to assume importance if the permanent cultivation of the crop be established. At the present time the only definite suggestion which can be made is that sugar-beet should not be grown on the same land more often than once in four years.

Old-established crops sometimes fall a prey to new diseases, or diseases which have hitherto been merely of trivial importance may rapidly become virulent. During the last few years the downy mildew of the hop (*Pseudoperonospora humuli*) has received prominence in this respect.

At first it was thought that this disease had been introduced into this country from abroad, but as the fungus has been recently found on wild hops in this country, it is possibly indigenous. Why, however, it has begun to attack cultivated hops only within the last few years is at present unexplained, but it may be that a more virulent form of the fungus has suddenly arisen. This new hop disease concerns all growers of the crop, and as it threatens to be of serious importance, hop growers will watch its development with some anxiety. So far it has been widespread only after a very wet season. This disease may affect the hop "hills," so it is clearly important to propagate new plants only from healthy "hills." Infected hop "hills" give rise to silvery stunted shoots or "spiked growths" in the spring. These should be cut off and burnt, otherwise spores will be formed on them, and these may be the means of starting an epidemic. Later in the season the extremities of the bines, when about five to seven feet high, may be similarly attacked, the consequence being that further growth is stopped. If these diseased ends of the bines

are destroyed, healthy lateral shoots will arise lower down which can be trained up to take the place of those cut off.

Spraying.—With a few fungoid diseases direct control by spraying the crop with a fungicide is best, as in some districts with potato blight. With diseases of this kind spraying is sometimes ineffectual solely because the fungicide is applied too late. Most fungicides are potent in protecting from disease only when applied to the crop before the spores, which disseminate the disease, are present abundantly in the air. Thus in the control of hop mould (*Sphaerotheca humuli*) it is the early sulphuring in May which is most effective in keeping the disease in check, although this must usually be followed by other applications of sulphur. With celery blight (*Septoria apii*), too, it is the early applications of Bordeaux mixture which prevent the outbreak of an epidemic attack, although if care be taken to use seed free from the germs of this disease there is comparatively little danger of a serious outbreak of this trouble.

Storage of Crops.—In the storage of root crops a balance must be struck between the

danger of frost and that of lack of ventilation. Adequate protection against frost must be combined with efficient ventilation, otherwise losses may be caused. In Scotland, where there is considerable danger of frost damage to turnips, it is best to cover the sides of the clamps or pits thickly with soil, placing only a thin covering over the top to allow of proper aeration. Only sound roots and tubers should be placed in the clamps, for certain diseases are very liable to spread therein. For instance, with carrots and other roots the fungus *Sclerotinia sclerotiorum* can cause immense damage in the clamps by producing a rot. Such a fungus does not develop spontaneously in storage, but under these conditions slightly diseased carrots are a source of infection, which spreads rapidly.

Some crops—*e.g.* onions—must be stored under dry conditions or they inevitably become rotten through attacks of fungi, especially species of *Botrytis*. Harvesting such a crop under dry conditions is very helpful to proper keeping, but if the onions are wet after harvesting they should be dried in some way. Sometimes, notwithstanding good conditions of

harvest, onions are kept in a damp or poorly ventilated atmosphere from which the bulbs absorb moisture, with the result that rot sets in. Excessive nitrogenous manuring of onions tends to induce a soft habit of growth, so that they readily fall a prey to fungoid rots in storage.

Burning Damaged Plant Material. — It is sound policy to destroy by fire all plant material affected by pests and diseases. Such hygienic measures are of supreme importance, but they are often overlooked. Many fungus spores can remain in a living condition in plant *débris* for long periods of time, and may ultimately be the means of disseminating disease. Such spores also often pass uninjured through the bodies of animals, and in this way disease may be spread with the dung. Fire is the only safe and cheap way of destroying these noxious agents. The reduction of the potential infecting units is one of the root principles of all sanitary measures, for if the sources of infection could be entirely destroyed there would be no pests or diseases. Such, however, is a counsel of perfection, but it is well within the range of

commercial practice to burn diseased or pest-ridden material as far as possible. The hop grower who fails to pick and destroy his mouldy hops, or the farmer who leaves piles of *débris* lying about his yards for insects to breed in, is storing up trouble for himself in succeeding seasons.

LIST OF REFERENCES

For descriptions of the various pests and diseases mentioned in this book the reader is referred to the *Leaflets* of the Ministry of Agriculture and Fisheries, 10 Whitehall Place, London, S.W.1, a list of which can be obtained free on application. The Ministry's *Reports on the Occurrence of Insect Pests and Fungus Diseases of Crops in England and Wales* also contain much valuable information. New discoveries in regard to methods of controlling pests and diseases are always discussed in the monthly *Journal of the Ministry of Agriculture* as soon as these discoveries seem likely to have a practical bearing.

The lack of general text-books dealing with the insect pests of *farm crops* is remarkable, and seems to be common to all countries. For a book on general agricultural zoology, students are referred to Theobald's *Agricultural Zoology* (Blackwood & Sons, London), and it may be added that *Insect Pests of Fruit*, by the same author, is the standard work on the subject. The principles of insect control as a whole are well described by Wardle and Buckler in *The Principles of Insect Control* (Manchester University Press). Foreign books in the English language deal chiefly with pests not found in Britain, but much of interest in regard to methods of controlling pests may be found in them notwithstanding. Those who desire to know what is done in North America may refer to Sanderson and Peairs's *Insect Pests of Farm, Garden, and Orchard* (Chapman & Hall, London), and Crosby and Leonard's *Manual of Vegetable Garden Insects* (The Macmillan Co., New York).

For books on diseases of crop plants the reader is referred to Massee's *Diseases of Cultivated Plants and Trees* (Duckworth & Co., London), and Eriksson's *Fungoid Diseases of Agricultural Plants* (Ballière, Tindall & Cox, London).

For books dealing principally with diseases of crop plants in the United States, Heald's *Manual of Plant Diseases* (McGraw-Hill Book Co., New York) and Chupp's *Manual of Vegetable Garden Diseases* (The Macmillan Co., New York) may be consulted.

Assistance in the control of pests and diseases in England and Wales can be obtained from the advisory entomologists and mycologists provided by the Ministry of Agriculture, who are attached to the following institutions :—

Armstrong College, Newcastle-on-Tyne.
Leeds University, Yorks.
Manchester University, Lancashire.
Midland Agricultural College, Sutton Bonington, Leicestershire.
Harper-Adams Agricultural College, Newport, Salop.
School of Agriculture, Cambridge.
The University, Reading, Berks.
School of Rural Economy, Oxford.
S. E. Agricultural College, Wye, Kent.
Long Ashton Research Station, Bristol.
Seale-Hayne Agricultural College, Newton Abbot, Devon.
University College of North Wales, Bangor.
University College of Wales, Aberystwyth.
University College of South Wales and Monmouth, Cardiff.

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